# AN ECONOMIC [illegible] ALTERNATIVE MANAGEMENT STRATEGIES [illegible] CONSTR[illegible]

BY

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AN ECONOMIC ANALYSIS OF ALTERNATIVE MANAGEMENT STRATEGIES FOR
THE SPINY LOBSTER INDUSTRY

by

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Florida's spiny lobster fishery has achieved tremendous growth in landings during the past two decades. However, the growth of input into the fishery has lately increased at a considerably higher rate resulting in declining catch rates, over investment and a potential for over exploitation of the spiny lobster stock.

This dissertation was designed to evaluate the current level of resource use, determine the maximum sustainable and economic yield levels, and analyze alternative lobster management programs. Biological and fire harvest analytical models were developed and estimated. Maximum sustainable yield was estimated to be approximately seven million pounds while maximum economic yield was estimated to be 5.8 million pounds annually, slightly above current levels. Optimum levels of input use are 215 licensed firms each fishing 795 traps. These levels require a 42 percent reduction in the number of firms in the industry with no reduction in number of traps fished.

Political and social considerations [illegible] yield not a feasible management alternative. In this case [illegible] of input (firm and trap) substitution was completed and pro[illegible] alternative input and output levels. Resulting cost, revenu[illegible] fit levels were determined for alternative program levels.

Specific management programs considered in the analysis [illegible] licensing, quotas and a harvest rebate program. For each [illegible] maximum yield levels, costs, revenues and profits were determ[illegible] the harvest rebate program alternative levels of administrat[illegible] and related sources of revenue were analyzed.

Chairman

# CHAPTER I

## INTRODUCTION

The Florida spiny lobster (*Panulirus argus*) is produced in the warmer ocean waters and is easily distinguished from its northern, cold-water cousin, the American lobster (*Homarus americanus*) by its lack of claws and relatively smaller size. Over the past forty years the Florida spiny lobster has developed from a casual food source of the inhabitants of the Florida Keys to an important commercial food resource. Second only to shrimp as a seafood, spiny lobster landings in Florida exceeded 11 million pounds in 1973 with an estimated retail value of over 40 million dollars. Over 1,100 licensed fishermen landed lobsters in 1973. Florida represents approximately 98 percent of U.S. spiny lobster landings (Appendix A). The Florida spiny lobster fishery is experiencing an ever increasing number of problems that require immediate attention by the legislature, regulatory agencies, and researchers.

One of the basic underlying forces creating problems within this fishery is consumer demand. Given the relatively fixed supply of stock, spiny lobster is now a preferred item in seafood markets and restaurants. An increasing tendency for U.S. consumers to eat in restaurants has created upward shifts in demand. The demand for spiny lobster is highly inelastic with respect to its own-price elasticity of demand (Allen [1]). U.S. consumption currently accounts for approximately 80 percent of the world spiny lobster production. Canada and

Europe account for approximately 10 to 15 percent while the small amount remaining is domestically consumed in the producing countries.

Between 50 to 60 countries produce and export spiny lobster tails to the U.S. The top four spiny lobster producing countries are Australia, Cuba, South Africa, and New Zealand. These countries produce approximately 65 percent of world landings while fifth ranked U.S. produces about 7 percent of the world total (U.S. Department of Commerce [48]).

Retail prices have increased substantially in recent years. In 1960 the retail price of spiny lobster tails was $1.50 per pound and the U.S. consumed 53 percent of the world production. By the 1970s U.S. consumption increased to over 80 percent of the world production of spiny lobsters. The 1970 retail price for spiny lobster tails was $3.43 per pound and reached $5.40 per pound in 1972. Currently, spiny lobster tails are retailed for as high as $9.27 per pound.[1] In roughly ten years retail price doubled and has almost tripled in the last five years.

Rising retail prices have encouraged increased exploitation of spiny lobster stocks. This has resulted in an increasing number of biological and economic problems in the Florida spiny lobster fishery. Some of these problems could also be credited to the nature of this industry or fishery. Unlike most economic enterprises the spiny lobster fishery is a common property natural resource which is characterized by unlimited entry. As such, the fishery generates excess use of inputs to maximize catch without any economic incentive to conserve or replenish the resource for future use.

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[1] January 24, 1975, average retail price for three seafood retailers in Gainesville, Florida.

The spiny lobster fishery is currently subject to some limited form of fishing regulation. Conservation directed regulations presently prohibit stripping eggs from females, specify trap dimensions so small undersized lobsters are released, close areas believed to be nursery areas, and specify a season which protects recruitment.

An investigation of the possible excessive use of resources in the industry gives reason for concern.[1] In the last 20 years the number of firms, defined as the sum of vessels and boats, increased from 54 in 1952 to 394 in 1972 (Council of Economic Advisors [18], Bell [3]). Number of vessels began increasing at an increasing rate around 1965. Simultaneously capital and labor inputs began to increase. From 1965 to 1972 firm members increased over 80 percent. Use of other inputs since 1965 also increased substantially. Number of traps by 242 percent, number of traps per firm by 60 percent, and number of fishermen by 101 percent (Appendix B, U.S. Department of Commerce [49], [50]).

Landings increased from 956,000 pounds in 1952 to over 5 million pounds in 1972. However, since 1965 landings have increased only 4.4 million pounds or 16 percent. Pounds landed per trap averaged 213 pounds in 1952, 49 pounds in 1965, and 20 pounds in 1972. From 1965 to 1972 dollars generated per trap decreased from $28 to $21, annual landings per firm decreased from 20,301 pounds to 13,069 pounds; and

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[1]Until 1975 approximately 50 percent of spiny lobster landings in Florida were harvested from the Florida domestic fishery. The remaining 50 percent were harvested in foreign water fisheries, primarily the Bahamian fishery. Approximately 100 percent of these landings were reported as Florida "east coast" statistics.

In 1975 the Bahamian government closed its fishery to U.S. fishermen. Due to this U.S. landings were down approximately 25 percent in 1975 compared to 1974 landings.

annual total revenue per fir[illegible] $11,423 to $14,003 (Appendix C).

During the 1952-72 period when total revenue increased at a decreased rate, costs of inputs used in the fishery steadily increased due to upward shifts in the demand for inputs. But, in recent years, input costs skyrocketed primarily due to rapidly increasing inflation which has been shown by changes in the consumer price index (CPI) for major inputs used in this fishery (Barnhart [2]). The CPI (1967 base) for petroleum products was 108.9 in 1972 and increased 109.5 points between 1973 and 1974. For wood products, the CPI was 144.3 in 1972 and increased 11.8 points between 1973 and 1974. CPI representing engines used in the fishery was 117.9 in 1972 and increased 31.0 points from 1972 to 1974.

Information on costs of inputs and returns for the 1973-74 spiny lobster season was acquired in a survey of captains of spiny lobster boats and vessels[1]. In 1959 the average spiny lobster craft ranged from fourteen-foot wooden skiffs that were either rowed or powered by an outboard motor, to larger wooden-hulled craft ranging in length from 26 to 34 feet and powered by 125 to 150 horsepower gasoline and diesel engines. Average cost of the skiff began at $150 while average cost of the engine and hull of larger craft ranged from $3,000 to $10,000. From the 1974 survey, average cost of only the engine was $8,257. This was based on a range from $500 for a 40 h.p. outboard motor to an excess of $60,000 for

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[1]The survey of 25 captains was completed in October, 1974. The random sample was stratified according to length of boat and area of fishery with confidence levels of 90 percent. Individual strata were weighted according to landings from these areas and size of boats in these areas.

diesel engines approaching 500 h.p. Average cost of the hull for this sample was $8,748. The range was from $400 for a sixteen-foot fiberglass skiff to over $20,000 for wooden and fiberglass vessels with a maximum length of 55 feet.

In 1959 a wooden lath trap complete with buoy and line cost an average of $6.00 each. In 1974 average cost of materials alone for a wooden lath trap was $11.00. The cost was a few dollars more if the trap was used for deep-water fishing. Average cost of fishheads used for bait was 5 cents per pound in 1959 compared with 11 cents per pound in 1973. The prime interest rate increased from approximately 6 percent in 1959 to 5.5 percent in 1973 signifying a substantial increase in the cost of capital.

Spiny lobster captains surveyed in 1974 claimed the costs of petroleum based products, such as polyethlene rope, styrofoam buoys and fuel, were triple 1973 prices. Engine costs were increasing at the rate of 15 to 25 percent per year. Fiberglass boats were increasing in cost at similar rates. Because of the shortage of cypress lumber the cost of cypress lath for trap construction was also increasing. In addition, the introduction of sonar and other fish locating devices, hydraulic pullers, and other harvesting improvements, has substantially increased the capital investment which the commercial lobster fisherman must make to remain competitive. The increase in number of traps used per fisherman represents a substantial increase in investment.

One problem that appears to exist in the fishery is a resource allocation problem . . . "over-investment" in capital (gear and craft) and labor (fishermen). Too many inputs are employed to produce a relatively fixed supply of spiny lobsters. This is reflected in the substantial

increases in inputs (traps, vessels, and gross tonnage) compared with the increase in landings. The broad over-investment problem of the fishery begins with the fishermen. Capital and labor investments increase at the fishermen's level due to (1) a struggle to overcome a severe price-cost squeeze; and (2) interdependencies in the production function creating negative externalities to the fishing firm or producer.

As a consequence of this increasing level of effort, a second problem of the fishery that may be occurring is one of "over-exploitation" of the fishery stock. Decreasing stock levels can cause serious long-term damage to the fishery and welfare of fishermen.

## Objectives

The overall problem is defined as one of resource allocation. The general objective is focused upon the determination of an optimal allocation of resources for selected price, cost, and fishery management alternatives. Optimal allocation may entail protecting the stock from reaching a level beyond recovery as well as regulating economic factors of the fishery.

The specific objectives are

(1) To identify the major factors affecting the quantity of spiny lobster harvested, and to estimate the harvest function of the Florida spiny lobster fishery;

(2) To evaluate the potential substitution between specific resources used to harvest spiny lobster in Florida;

(3) To determine an optimal combination of inputs for the Florida spiny lobster fishery; and

(4) To evaluate the impact of selected management programs on resource allocation in the fishery and on the optimum combination of inputs used by firms. Specific programs considered are limiting licensing of firms and traps, establishing landings quotas, and a harvest rebate program.

The results of this study will provide a basis for establishing guidelines for managing the Florida spiny lobster fishery. The focus is on the analysis of management strategies which might help reduce the cost and difficulties of regulating effort. In addition, study results can be conceivably viewed as a case study applicable, at least in approach, to other marine resource allocation problems. Finally, individual fishermen may use the results of the production analysis as a basis for both long and short-run decision making.

## Scope

Spiny lobsters landed in Florida are harvested from the domestic Florida spiny lobster fishery and foreign water spiny lobster fisheries.[1] More than 95 percent of spiny lobster landings harvested from the domestic fishery are landed in Monroe County. These landings comprise approximately 50 percent or more in past years of all spiny lobster landed in Florida. Without the Bahamian fishery, landings from Monroe County make up over 90 percent of U.S. spiny lobster landings. Consequently, although the scope of this study is defined as the Florida spiny lobster fishery, the data for the empirical analysis are delineated as that of the Florida Keys or Monroe County, Florida.

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[1] The majority (approximately 90%) of foreign water landings were lost as a result of the 1975 closing of the Bahamian fishery.

A literature review of theoretical and/or applied bioeconomic research is presented in the next chapter. The theoretical model is presented in Chapter III while the data and empirical model are presented in Chapter IV. Results of the analyses and their practical interpretation are given in Chapter V. Four management alternatives and resulting policy implications are reviewed in Chapter VI. Chapter VII, the final chapter, includes a summary, conclusions, and suggestions for further research.

# CHAPTER II

# LITERATURE REVIEW

## Introduction

Previous empirical spiny lobster (*Panulirus argus*) research is summarized and some major theoretical and empirical bioeconomic management studies are capsuled in this chapter. This information is the minimum necessary to understand biological and psychological relationships considered in the design of management programs. Furthermore, existing laws must be understood before alternative programs can be considered and thus they are reviewed in this chapter. None of the empirical bioeconomic studies consider the spiny lobster fishery, but they do include analyses of management strategies which may be applicable to the spiny lobster fishery. Several recent bioeconomic studies such as Bromley [8], Fullenbaum [26], and Van Meir [53] contain extensive and thorough reviews of past theoretical and empirical studies. This chapter contains a review of selected theoretical concepts and empirical studies directly applicable to this study. The reader is referred to the more extensive reviews where appropriate.

## Spiny Lobster Research

There is a lack of economic analysis concerned with management of the spiny lobster (*Panulirus argus*). Several empirical studies deal primarily with biological characteristics, environmental conditions and physical production analysis of fishing craft, gear, and techniques

Scientific research in the U.S. on spiny lobster began as early as 1916 (Allen [1], Barnhart [2], and Crawford [19]), but it was not until 1944 that an investigation of the Florida spiny lobster fishery was conducted by the Marine Laboratory at the University of Miami (Smith [42, 43]). A review of studies since 1948 provides considerable information that may be useful in explaining the behavior of landings (Smith [42, 43], Cope [17], Butler and Pease [9], Dees [22], Chislett and Yesaki [15], and Ting [46]).

Smith's publication in 1958 [43] provides a most complete discussion of the Florida spiny lobster fishery including taxonomy, biological cultivation, fishing gear and methods, dollar value and importance of the fishery, and state regulations of the fishery. Several other studies published since 1958, including Butler and Pease [9], Chislett and Yesaki [15], Cope [17], and Ting [46], updated some of Smith's findings.

Butler and Pease [9], and Chislett and Yesaki [15] determined the feasibility of developing spiny lobster fisheries off coasts of Panama and Jamaica, respectively. Although they primarily compared types of gear and fishing techniques, some biological and environmental observations were documented. Cope [17] analyzed alternative gear and fishing techniques in the Florida fishery. Finally, a recent study by Ting [46] analyzed the potential for spiny lobster cultivation from a physical production standpoint but alluded to economic implications. The information obtained from these studies is briefly summarized.

The Florida spiny lobster (Panulirus argus) is one of 30 species distributed nearly world wide in tropical and sub-tropical waters. They differ from the Northern cold-water lobster (Homaridae family) in that they lack claws and have long antennae for sensing food and danger.

They are smaller and have numerous spines covering their back (cape) for protection against many natural enemies. The average legal size landed in Florida weighs approximately one and a quarter pounds and is 10 inches long, although in 1968 maximum lengths of 17 inches and weights in excess of 10 pounds were not infrequent (Deas [22]).

Spiny lobsters generally feed at night on a wide variety of foods, primarily small crustaceans. They also forage. During the day they hide in rocks, coral, and other marine growth but are known to resort to cannibalism when crowded. Growth is primarily dependent upon the environment. As body weight of the spiny lobster increases the hard outer shell is shedded. This shedding of the shell is called molting and occurs several times throughout the life cycle. The body weight increases approximately 5 percent during each molting stage. Although younger lobsters molt more frequently, it takes approximately five years for them to reach legal size.

Female spiny lobsters do not begin reproducing until they reach a length of eight to nine inches. An eight-inch spiny lobster can produce approximately 50,000 eggs compared with 500,000 eggs produced by a 14-inch lobster. In Florida, mating occurs February through June in shallow waters. The eggs are hatched in deeper water three weeks later. It takes the young larvae three to six months to conform to the shape of the adult lobster. At this stage the young lobster drops to the ocean floor and is approximately 7/8 inch long. The mortality rate from hatching to this stage is hypothesized to be over 99 percent.

Water temperature, food supply, reproduction and weather influence the migration of spiny lobsters. Usually migration occurs between deep and shallow water but sometimes migration is north in the summer and

south in the winter. Extremely cold weather, extended periods of unseasonable weather, or still, calm weather can cause lobsters to migrate to deeper water (Smith [43]). This is contrary to the findings of Butler and Pease [8] that spiny lobsters prefer shallow waters. Smith [43] also reported that spiny lobsters are believed to have migrated over 1,000 miles but generally do not migrate over five miles.

No evidence is available to indicate whether they migrate over deep straits, but it is believed that long movements lead to a gradual mixing which, over time, results in an equalization of the stock. Consequently, the biological stock of a geographical area, characterized by a deep water perimeter, should be treated as a single unit. As such, changes in any part of the fishery will eventually affect the whole fishery. Conversely, as part of the fishery becomes "fished out" it will replenish itself if left alone for a period of time. Some evidence suggests that maximum exploitation of most spiny lobster stocks in the Caribbean have been reached, with the possible exception of the southern edge of the Caribbean Sea (Idyll [31]).

The major portion of commercial lobster landings in Florida are harvested at depths of less than 50 feet using wooden traps. At least 80 percent of annual landings are harvested in the first half of the season which lasts from August 1 through March 31. Generally, one to three fishermen per craft fish 200 to 1,000 traps. Length of the craft range from 16 to 55 feet. They usually travel less than 25 miles and return the same day. Based on the theory that a trap offers protection it can be fished without bait. However, freshly baited traps are preferred. There appears to be no difference in landings between traps baited with cowhide, which lasts longer, and traps baited with fish.

New traps catch better after being in the water at least five days. Landings are higher if traps are lifted every two to three days rather than every four days. Traps settling on the bottom collect silt and foreign matter, which past experiences indicate reduce landings if the exterior of the trap is not brushed every few days. Landings are higher for traps set next to reefs or forage areas than for traps set on reefs and in flat clean areas.

Butler and Pease [9] found that bottom temperature and salinity were correlated with the presence of lobsters. In a range of 68°-85°F more lobsters were landed than in higher bottom temperatures of the 83°-85°F range. Also in a total salinity range of 28°-34°/00 landings were higher than at the 31°-32°/00 salinity level. Lobsters will not feed when water temperatures are near freezing and will migrate from locations with colder water temperatures to warmer water locations. A study on surface and subsurface water temperature shows that the majority of the fishing area in the Florida spiny lobster fishery is isothermal year round (Robinson [38]). This means that in depths of less than 50 feet the difference in the bottom temperature and surface temperature is insignificant.

Aquaculture of spiny lobster is possible but currently not economically feasible because they require very exacting care and specialized conditions (Ting [46]). Spiny lobsters require clean, oxygenated water with a balanced temperature and the individual lobsters kept separated. To accomplish this requires a large volume of space and labor and thus a large capital investment. The growth period from juvenile to marketable size is approximately three years in an artificially created environment, compared with five to seven years in the natural environment.

## General Bioeconomic Management Research

Researchers have been contemplating bioeconomic management of the fisheries at least as far back as the 1920's as evidenced by Kirk's [38] work on the Gulf of Maine fishing grounds in 1929 and Russell's [40] work in 1931 titled "Some Theoretical Considerations on the 'Over-fishing' Problem." In 1943, Herrington [29] considered alternative methods of fishing management and Nesbitt [34] investigated the biological and economic problems in management of fisheries.

Major theoretical contributions emerged in the early 1950's in the writings of Schaefer [41], Gordon [28], Christy and Scott [16], Crutchfield and Zellner [21], and Turvey [47]. These antecedents of the past twenty years are generally credited with developing the fundamental bioeconomic theory. Their differences can be briefly analyzed on the basis of four management objectives. Schaefer's biological approach was concerned with maximizing production from the sea in a strictly physical production framework. The others were oriented toward the maximum economic yield concept but differed to a slight degree. Gordon, and Scott and Christy actually defined a monopoly situation as optimum with an objective of maximum economic yield above costs. Crutchfield and Zellner's approach was the same but excluded returns due to monopolistic practices in order to maintain consistency with federal regulations on monopolies. Turvey also maximized economic yield excluding returns to monopolistic practices but, in addition, attempted to maximize consumer surplus.

More recent research deals with the empirical application of the above concepts and with some refinements to the theory. Lampe [32] used a dynamic model of the Cobweb form to investigate the interrelationships

rionships between biological and economic aspects of commercial fisheries. Carlson [11, 12] developed a theoretical yield function by integrating an economic production function with a biological growth model and distinguished between firm and industry or aggregate production functions. Von Weir [53] demonstrated that landings will exceed maximum sustainable yield (MSY) as a result of excess effort generated in a competitive economic system such as the George's bank haddock fishery. To curtail effort at MSY he suggested free entry with landings quotas, monopolistic exploitation implying the maximization of net revenue above labor and capital cost, or quotas placed on fishing effort. A problem inherent in all of these alternatives is defining a unit of effort. Smith [44] developed a dynamic competitive model of the interaction between the number of firms (investment) in a fishery and the population of an exploited fish species, which included crowding externalities.

Bell's [3, 4, 5, 6] empirical research dealt primarily with firm analysis and illustrates the use of econometric techniques in marine research. He attempted to determine what factors influence the rate of return and what impact their variability has on the industry. A major criticism of his findings is that the estimates will not withstand rigorous statistical tests primarily because of model misspecification and lack of a randomly selected sample.

After an extensive review of literature the major revelation can best be expressed by a quote from the concluding statement of the abstract of a dissertation written in 1965 (Crowley [8, p. 36]) -- "The presence of considerable uncertainty in a fishery, and the lack of perfect knowledge on the part of biologists and economists, renders as sweeping conclusions of traditional writers in fishery, and their subsequent

policy recommendations, particularly vulnerable to introduction. Since the time of this statement considerable documentation of theoretical and empirical marine research has accumulated, yet one has to agree that the quoted statement can still carry conviction today. This is not to imply that the research is not useful, but rather that a need still exists for data, authenticated tools, and methodologies for research applicable to the bioeconomic management of today's marine resources. Many of the works to date develop interesting statistical investigations while others hinge on highly abstract optimization criteria.

The major reason that the success achieved in traditional agricultural research, particularly in estimating production functions, has not been achieved in marine economics research is partly due to basic underlying problems that have yet to be solved in analyzing marine resources. These problems relate to the techniques, assumptions, and empirical limitations (i.e., lack of biological, environmental and economic data) and are characteristic of the common property nature of bioeconomic resources. The very few exceptions to this lack of success have occurred with species existing in what may be termed "closed systems," in which the researcher had considerable control over the individual variables. Very often the problems are related to inadequate specification of the theoretical bioeconomic structure of the fishery, lack of appropriate biological and economic data, lack of multidisciplinary research cooperation in designing models oriented towards a systems approach, misunderstanding the needs of counterparts in a multidisciplinary team, and often defining objectives discordant to the researchers or policy makers.

This is evidenced in a recent publication edited by Sokolski [45] in which several researchers addressed the issues and problems encountered when dealing with research directed toward managing marine resources. Sokolski defined a critical area of marine resources research to be the measurement of the gap between the "optimum" management solution for a given fishery and current management arrangements. To emphasize the relative lack of success with this objective, he listed several critical issues that have been complicating current research efforts. They were characterized as empirical and conceptual in nature and multidisciplinary in scope. One conclusion drawn after reviewing this publication is the fact that substantial uncertainty exists with respect to the reliability of results in marine economics research and accordingly the proposed management programs. Many of these problems need to be solved before sound management programs can be developed for many of the species. Determination of optimal solutions will require considerable time, effort, and financial resources.

Pontecorvo [35] pointed out in his work with Pacific red salmon that the costs of improving information may exceed the benefits. This should be taken into account when deciding the value of increasing the sophistication of models designed for direct applicability in managing a particular fishery. Consequently, when a researcher is given the task of developing management alternatives for a currently existing real problem as is the case of the Florida spiny lobster fishery, he is often not allowed the luxury of exhausting all methodological possibilities in his investigation due to the reasons previously discussed. Because of this he uses what resources are available, such as traditionally acceptable or validated theories in economics and marine biology. For

example, such resources include productian functions exhibiting diminishing marginal rates of return, downward sloping demand for a commodity, and the bio mass or population of a fish species which is in part dependent upon its environment and thus exhibiting a semi-sphere-shaped yield curve.

Given lack of data, particularly biological data, and lack of precise models which lend themselves to rigorous statistical testing, it would appear that a reasonable criterion for model building would be "Occum's razor," — the simpler the better. This may not be too unreasonable since statistical testing may be more efficient, the results are timely, completion of the project remains within the limits of the budget, and it is questionable whether more sophisticated models requiring more resources would improve the results. In light of these observations, the approach for this project presented in the next chapter does not attempt to improve the theory or apply overly-sophisticated empirical models or models requiring inapplicable assumptions or data which are not available.

## Fisheconomic Lobster Research

Fisheconomic research related to the Northern American Lobster fishery, Bell, 1970 [3], Bell and Fullenbaum, 1972 [7], Dow, Bell and Herriman, 1973 [24], Huq, 1973 [30], and DeWolf, 1974 [23] were considered in the development of the present models. The latter two publications by Bell are extensions of his early work on the American lobster industry. All three of Bell's publications analyze impacts of different types of management programs through changes in a general equilibrium model. In Bell's first publication [3], a linearly

additive structural production function is specified as an average product function. From the estimation a simple parabolic yield function was derived. Number of traps was the measure of a unit of effort. Bell and Fullenbaum [7] developed a production function which was derived from an integration of a logistic growth function, an industry production function and an industry revenue relationship. The model includes a biomass variable over time, environmental constraints, total industry cost, a technology variable and other parameters to be estimated, such as catching power of a unit of effort. Variables for which data are lacking are either assumed away or are assumed to be represented by some proxy and ultimately the whole model collapses into a simple second degree polynomial equation presented in Bell's earlier publications. The model appears to be considering all the necessary components of a total bioeconomic system when, in fact, Bell does not have direct measures of all independent variables in the first model. Dow, Bell, and Harriman [24] utilized this model and incorporated updated data for the bioeconomic model and some biological information on the Northern American lobster such as history, migration, disease, etc.

Huq [30] analyzed labor mobility and social transfer costs of three representative lobster fishing communities in Maine. Huq concluded that substantial immobility and limited employment opportunities exist in the fishery and thus the human element must be seriously considered in designing any management program.

Finally, Dobell [23] investigated Canada's lobster fishery. Biological and economic bases of fishery regulations were examined. Also examined were the economic effects of regulations on the fishery, such as total industry value, total landings, and net return per fisherman

No quantitative statistical model was used and efficiency (net returns) was the criterion for evaluation. The conclusions were that previous regulations of limiting effort have led to economic inefficiencies but that economic conditions outside the fishery have had an even greater impact on its present structure.

## Regulatory Management Programs For Florida Spiny Lobster[1]

Florida laws are designed to regulate the spiny lobster fishing industry for the purposes of insuring and maintaining the highest possible production of lobster, or in other words, the maximum sustainable yield. These laws have basically represented biological goals and attitudes, but in recent years the need for economic considerations in management schemes has been recognized by all concerned. During the early 40 years prior to 1965, Florida management was mainly concerned with the conservation of the spiny lobster population through controls on minimum size and fishing seasons. These regulations are still of importance in the total management program. Although most of the earlier regulations have been revised and new regulations added since 1965, gear regulations were first emphasized in the 1965 legislation. Perhaps more important in the 1965 legislation was the emphasis on the need for effective policing policies through the use of marketing by permit number, and gear and boat identification for surveillance.

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[1] The regulations discussed here are as of March 31, 1976. A more detailed discussion of the present laws and historical pattern of Florida spiny lobster regulations can be found in a review by Prochaska and Eberle [36].

A $50 permit is required for all persons intending to catch more than 24 lobsters per day. The permit must be carried on the person at all times and can be suspended or permanently revoked upon the arrest and conviction of a permit holder for violation of any of the lobster fishing laws.

Florida's management program includes two regulations pertaining to the gear and craft. The first is that all gear (traps and buoys) and the craft must be permanently identified by the permit number and/or color code assigned to the fisherman upon receipt of his permit. The figures on the craft must be at least three inches high to permit easy identification from the air. The second regulation pertains to the specific gear requirements. Wooden traps, ice cans, drums, and other similar devices may be used provided that they are not equipped with gratings, spears, grabs, hooks, or similar devices. The traps must be designed out of wooden slats not to exceed 3 x 2 x 2 feet or the cubic equivalent. Only the sides of the traps may be reinforced with 1b gauge, one inch poultry wire.

Any gear used to capture lobsters must be marked by a buoy. Up to twenty traps can be attached to a trot-line, and the line is marked at each end by the attachment of a flag buoy. Buoys used must be of sufficient strength and buoyancy to remain continuously afloat. Any device not conforming to the specifications listed, or not carrying a valid permit number, may be seized and destroyed by enforcement officials. It is unlawful to interfere with anyone's traps or markers without the owner's permission.

In 1953 the closed season was set between April 15 and August 15, and in 1955 it was placed at its present interval of March 31 to

August 1. The 1965 act provided that traps may be placed in the water and baited ten days prior to the open season and must be removed within five days after the closing of the season, though no lobsters can be taken during the closed season.

Three types of restrictions on the condition of lobster caught in Florida exist at present. These deal with minimum size, separation of head and tail, and egg-bearing females. The minimum size allowed is a three-inch carapace or a 5 1/2 inch tail, though the tail measurement is inapplicable if the tail is separated from the body. If head and tail are separated under required legal permit, the tail must have a minimum length of six inches. The 1965 act prohibited the catching of egg-bearing female lobsters, and those found in traps are to be returned alive to the ocean. Stripping eggs from them is also prohibited. That same act required a special permit if the separation of head and tail was to be done before landing the lobster. A permit for such separation may be granted if the operation is so far from land that it is not practical to keep the lobsters alive until landing them.

Historically, in 1929 the first size restriction was enacted, the minimum being one pound avoirdupois. In 1953 the minimum was redefined to be a lobster with a tail measuring six inches. The 1953 act redefined the minimum size by tail and carapace measurement, with a minimum carapace measurement of three inches and tail measurement of 5 1/2 inches. Methods of measurement were also given. Finally, a 1959 act allowed a six-inch minimum on tails separated under special permit.

Presently, no legislation has provided for limited traps per firm, limited licenses, landings quotas or taxes on landings to restrict the over employment of labor and capital in the fishery. Groups with common

interests in and recent concern for the welfare of the fishery have expressed a need for information describing the benefits and consequences of such regulation.

## CHAPTER III

## THEORETICAL MODEL

This study dealt with the management of a living marine resource and the consequences of management strategies on the resources and its uses. The production of living marine resources differs from traditional production processes in that it requires the capture of a wild animal without the more traditional production, cultivation and/or manufacturing of the products involved. Biological behavior of the animal, changes in its environment and economic factors of production (labor, capital, management, and land) influence the success of capture or amount of product entering the market.[1] This relationship between the product, defined as landings, and the above factors or variables that influence landings, was defined as a harvest function. The analyses presented in this study were based on the estimated harvest function for the Florida spiny lobster resource. The theoretical framework of a fishery harvest function is presented in this chapter. A biological growth model of a fishery was combined with the influence of man in the form of fishing effort and termed a bioeconomic model. Finally, the procedure in which the bioeconomic model was used to satisfy the remaining objectives of the study is presented.

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[1]Assuming all that is captured enters the market.

## Biological Theory of a Fishery[1]

The harvest function, or yield function, (Equation 1) from a biological point of view represents the level of biomass (or stock of fish) that can be harvested. The equilibrium level of biomass is that which can be harvested without changing or damaging the parent stock. The yield function may be expressed as

$$Y_B = f(\text{Stock}) \tag{1}$$

where,

$Y_B$ = the amount of biomass available for harvest, and

Stock = the total biomass of fish.

This system is exclusive of the influence of man. Biological theory states that the change in the stock of a fishery will follow an S-shaped curve as shown in Figure 1. This theory has been supported by findings from population studies of deer and insects. Additional support is presented in a recent study by Gates and Norton [27] who estimated an S-shaped curve for the yellowtail flounder fishery of New England. An S-shaped curve suggests that the population increases (a) slowly at lower levels, limited by the reproductive capabilities of smaller numbers and the smaller number of fish that are sexually grown, (b) rapidly in the intermediate range, as larger numbers of fish produce more eggs than can survive and food supplies are adequate, and finally, (c) slowly at higher levels where pressure from limited food supplies impedes the population growth in an equilibrium manner and deaths just offset births. Therefore, stock is a function of the biological

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[1] The material in this section was primarily developed from the following references: Bromley [8], Carlsen [10], Christy and Scott [16], Cheung [14], and Prochaska and Ekanda [36]

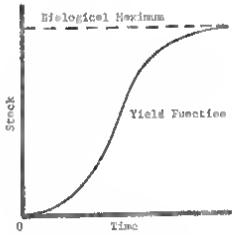


Figure 1. Growth curve for a fishery stock

relationship between the parent population, the mature progeny, and the influence of the environment on this biological process. The following implicit relationship is suggested:

$$S = g(S_1, S_2, S_3) \qquad (2)$$

where

$S$ = stock

$S_1$ = population of mature progeny,

$S_2$ = parent population, and

$S_3$ = environmental attributes affecting the biological behavior of the stock

The population of mature progeny ($S_1$) is a function of the parent population ($S_2$) and the environment ($S_3$). Also determining the level of mature progeny is the number of young or recruitment, the rate of growth

of the progeny and the natural mortality [illegible] changes in the biological process. Parent population [illegible] the environment, growth rates, and mortality rates [illegible] response of the parent population to the variables may differ [illegible] parent stock.

Numerous environmental factors significantly affect the biological process. Significant factors are the food supply [illegible] man and hydrographic characteristics including water temperature, salinity, bottom conditions, currents and atmospheric [illegible].

The relation between the number of mature offspring and the parent population may be derived from these basic biological relationships. The recruitment of mature progeny is of particular interest since that is an important policy variable used in developing management schemes that will maintain some equilibrium level of catch. The relationship between mature progeny and parent population is a function of the same variable affecting growth. At very low parent population levels recruitment is low because the number of spawners is small. As the parent population increases, the level of recruitment increases. After some population level is reached, recruitment levels decline for reasons due to the environment and biology of the species, such as unhealthy fish stocks, an inadequate ecological niche, declining growth rates, increasing mortality rates, severe competition for food, and adverse hydrographic conditions. Thus, at some intermediate population level, the ability of spawners to recruit progeny into the standing population is a maximum. At low population levels, growth rates are relatively low, but beyond some population level, the growth rates decline and natural mortality rates are relatively high.

Relatio[illegible] [illegible] in [illegible] time period [illegible] number of mature progeny in the following time period may be summarized as in Figure 2 (Prechaska [36]). The 45° line, OA, represents the level of mature progeny necessary to maintain the parent population at its present level. That is, OA traces out the number of mature progeny, measured on the vertical axis, necessary to replace the parent population measured on the horizontal axis. The curve, OM, represents the actual number of mature progeny that will be produced by each parent population level. For example, a mature progeny of $M_1$, will maintain a parent population of $P_1$, an parent population of $P_1$ will produce $M_2$ and the total fish stock will increase. This process will continue in nature until the actual production of mature progeny

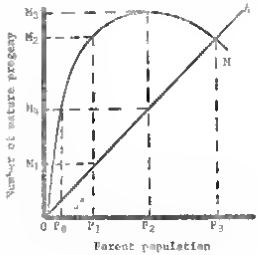


Figure 2. Number of mature progeny as a function of parent population levels

just equals that necessary to maintain a stable population, [illegible] $P_3$ where the lines intersect. At population $P_2$ total production of mature progeny is a maximum, and at $P_1$, the excess of mature progeny over that necessary to maintain the parent population is greatest.

The introduction of successful fishing effort while the parent stock is $P_3$, will reduce the parent population since there is no net recruitment with parent stock $P_3$. The reduction of parent stock in the initial time period results in an increase in the production of mature progeny in the following time periods. Increased fishing effort may continue to reduce the parent stock until parent stock, $P_1$, is reached. Parent stock, $P_1$, will produce the largest marketable surplus defined as equilibrium harvest and represented as $M_2 - M_1$ in Figure 2. Maximum marketable surplus is not at the parent population level which produces the maximum mature progeny ($M_3$). If in any time period more than the equilibrium harvest is taken, the parent population will move $P_0$ and again the equilibrium in following periods will be reduced. If the level of fishing is that which exactly takes the excess over the needed replacement each season, parent population, $P_1$ will be maintained. This is defined as maximum sustainable yield (MSY).

The equilibrium harvest shown as the area between the mature progeny curve, OI, and the replacement line, OA, in Figure 2, may be expressed in Figure 3. Points $P_0$, $P_1$, $P_2$ and $P_3$ correspond with population levels in Figure 2. The maximum sustained yield, $Y_{P_1}$, is produced from population $P_1$ which corresponds to $P_1$ in Figure 2. Except at the maximum sustained yield the same equilibrium harvest may be taken at different levels of parent population. For example, equilibrium

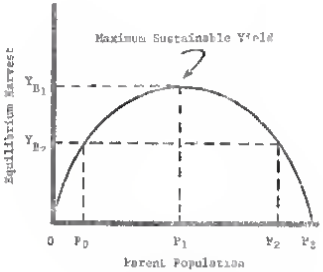


Figure 3. Equilibrium harvest as a function of parent population

harvest, $Y_{B_2}$, may be taken with either parent population $P_0$ or $P_2$. MSY occurs at that point of equilibrium harvest curve where its slope is zero.

## Traditional Economic Production Model

A production function normally used in economic analysis is defined as the relationship between physical inputs and a resulting level of physical output, similar to the biological yield process. The difference occurs in the type of relationship between the inputs and the resulting output. Similarly, theory exists that explains the economic stages of a production process in an economic system.

Production inputs or factors of production can be defined as units of effort and consist of land, labor, capital, and management. The

production process can be defined as

$$Y_E = f(E) \tag{3}$$

$$E = g(E_1, E_2, E_3, E_4) \tag{4}$$

such that,

$$Y_E = f(E_1, E_2, E_3, E_4) \tag{5}$$

where,

$Y_E$ = output as a result of effort,

$E$ = effort = combined unit of inputs, $E_1 \ldots E_4$,

$E_1$ = land,

$E_2$ = labor,

$E_3$ = capital, and

$E_4$ = management

The assumed objective for firms in the industry is profit maximization. All firms are assumed to operate in a rational economic manner with production occurring under conditions of decreasing returns. The industry is assumed to have an atomistic structure with constant factor prices and independent production processes.[1]

The biological yield function (Equation 1) is actually a physical relationship between the various exogenous biological and environmental attributes and the available fish stock for harvesting. The production function (Equation 3) is a physical relationship between output and exogenous variables representing effort. Biological models of fishery populations without economic considerations are of little value as a tool for developing useful policy for fisheries management. Likewise, an economic model devoid of biological considerations is also of little

[1] The reader is referred to Ferguson [25] or Carlson [13] for a complete presentation of production economics.

value. Thus, the integration of biological and economic considerations is needed to accurately estimate the relationship between that level of product which reaches the market (i.e., pounds landed) and those variables that determine that level of product. This process is necessary to insure that the equilibrium harvest level is both biologically and economically sufficient.

## Bioeconomic Model

Variables of the yield function (Equation 1) and the production function (Equation 3) were integrated to form the bioeconomic model or the harvest function:

$$Y_{BE} = b(S, E) \qquad (6)$$

Substituting equations (2) and (4) into (6) gives

$$Y_{BE} = b(S_1 + S_2 + S_3, E_1 + E_2 + E_4), \qquad (7)$$

where,

$Y_{BE}$ is defined as the bioeconomic equilibrium yield.

The biological yield model and the production model provide the basic foundation from which proper management policies are designed. Management policies consider equilibrium harvest ($Y_B$) that does not endanger the parent population ($S_2$) while allowing maximization of harvest ($Y_E$) for a given level of inputs. This approach to managing a fishery is known as maintaining maximum sustainable yield (MSY). MSY was previously defined as the greatest equilibrium yield possible without damaging the parent stock and varies in the long-run as a result of effort, biological changes in the stock, and environmental inducements. MSY is an important variable in designing accurate management policies.

MSY expresses a physical relationship and has provided the basis for conservation programs of U.S. fisheries with little concern about the economic consequences on the fishermen or society (Sokolinski [45]). In recent years this philosophy of management practices has changed and economics has entered the areas of fishery resource management. Such things as factor prices, product prices, costs, and other pecuniary attributes of the "bioeconomic system" must be considered for proper management of a fishery. In many policy makers maximum economic yield (MEY) is now considered the objective of "proper" management as is assumed throughout this dissertation. MEY occurs at a level of landings which are less than those suggested by the MSY criterion and thus requires less fishing pressure.

MEY is defined as that yield where net revenue (NR) is maximized for the fishery. Net revenue for the industry is at a maximum where the greatest positive difference occurs between total revenue (TR) and total cost (TC), as illustrated in Figure 4. MEY occurs where the slopes of the TR curve and TC curve are equal and can be expressed as follows:

$$MEY = \frac{\partial TR}{\partial Y_{BE}} - \frac{\partial TC}{\partial Y_{BE}} = 0, \qquad (8)$$

where

$\frac{\partial TR}{\partial Y_{BE}}$ represents additional or marginal revenue to the industry for additional landings, and

$\frac{\partial TC}{\partial Y_{BE}}$ represents additional or marginal cost to the industry for additional landings.

Industry total revenue (TR) is derived by multiplying the harvest function ($Y_{BE}$) by ex-vessel price per pound (P). As ex-vessel price

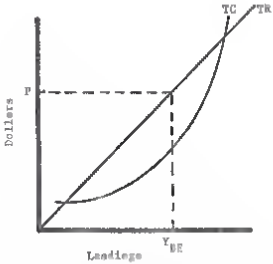


Figure 4. Maximum economic yield (MEY) for the industry is illustrated as the greatest distance between industry total revenue (TR) and industry total cost (TC) with respect to landings

increases the TR curve shifts up and conversely TR shifts down as ex-vessel price decreases. Industry total cost (TC) is defined to be a function of the exogenous variables of the harvest function ($Y_{BE}$) and their related prices. TR and TC may be expressed as

$$TR = Y_{BE} \times P \tag{9}$$

$$TC = h(S,E) \tag{10}$$

One fisherman's harvest function is theoretically interdependent with all other fisherman's harvest functions. Landings for one fisherman are affected by what other fishermen catch from a given stock. Consequently, as the number of firms in the industry increase, each firm's production function constantly shifts downward while the associated cost functions shift upward. Per unit costs increase for the same amount of effort expended because of fewer landings per unit of

effort. Costs per unit of output eventually rise to a level where entry into the industry ceases.

Crutchfield [20, p. 12] identified the consequence of such a criterion when he said, "... such a market, unregulated, will destroy itself either economically or biologically." Or in Carlson's [11, p. 7] words, "In common property resource, the 'invisible hand' guarantees that the market will strive at a solution that is suboptimal."

## Summary

Biological and economic theory suggests the following bioeconomic harvest model.

$$Y_{BE} = f(S_1, S_2, S_3, E_1, E_2, E_3, E_4). \tag{11}$$

Major focus of this analysis entailed determining the appropriate input level and subsequent landings where the greatest net revenue is generated to the fishery. Net revenues for various levels of effort such as number of firms in the industry and number of traps were compared. The feasibility of alternatives for limiting effort were assessed by considering the impacts these have on net revenues per firm, number of displaced firms, total revenues to the state from user fees, cost and time of implementation and enforcement of regulations, and expected public acceptability.

Development of the theoretical model for this study has resulted in an examination of the biological theory of a fishery resource and a brief discussion of production theory. Models of these two theoretical frameworks were integrated into a bioeconomic model used to explain the theoretical constructs of management goals, namely MSY and MEY. The empirical model and data analysis are presented in the next chapter.

# CHAPTER IV

## EMPIRICAL MODEL AND DATA

The empirical model and estimation procedure are presented in this chapter in three parts. Types of data used are included in the presentation of each structural equation. Delineation of the study area and the method of data acquisition is presented in the final section.

Estimation and theoretical analysis of the industry harvest function are presented in the first part of the chapter. The second part of the analysis is concerned with estimation of a firm harvest function and associated optimum resource allocations for the firm at estimated fishery stock levels. Implicit industry factor prices and costs were derived in the firm analysis. The final part of the analysis involved integrating the results from the industry and firm analyses to estimate maximum economic yield (MEY) for the industry.

### Definitions

A few definitions at this point may help clarify relationships within the model. The industry harvest function was estimated using secondary time-series data for 20 years from 1952-71. The firm harvest function was estimated using primary cross-sectional data obtained from a survey conducted in 1974 of 25 full-time spiny lobster fishermen. Capital letters are used to represent variables relating to the industry harvest function, while lower case letters are used to represent variables related to the firm harvest function. The only exception to this

is $P_y$, which is always used as the ex-vessel product price per pound for the industry and for the firm. Industry landings are represented by Q and firm landings are represented by q. Variables representing inputs into the industry harvest function are $X_1$, $X_2$, and $X_3$. Firm harvest function input variables are $x_1$, $x_2$, $x_3$, $x_4$, $x_5$, and $x_6$. In only one case does a variable from the industry harvest function and the firm harvest function represent a similar measure of inputs, number of traps. $X_1$, from time-series data, represents average number of traps per firm in the industry for a given year, while $x_1$, from cross-sectional data, represents the number of traps fished by a given firm. An asterisk (*) superimposed on a variable, for example $x_1^*$, denotes the variable as an optimum solution and facilitates its identification when substituted in different equations.

## Bioeconomic Analysis

Time-series analysis is necessary to determine the direct and indirect effects of increased effort on catch. Resulting effects of the traditional economic production relationships are defined as direct. Indirect effects are the influences on landings from variations in the fish stock due to variations in effort. Time-series analysis is necessary because an analysis for only one point in time will only consider the effect of effort on landings for the given fishery stock in existence at that time. Evaluating effort over time also allows for the consideration of expanding effort on the extensive margin--more firms in the industry.

The bioeconomic model set forth earlier can be restated as

$$Y_{BE} = h(E_1, E_2, E_3, E_4, S_1, S_2, S_3) \qquad (12)$$

In the lobster fishery $E_1$ (land) is not a factor, therefore, $E_1$ drops out of the theoretical equation. $E_2$ (labor) and $E_4$ (management) are transformed into output in the production process through the fishing traps (the primary type of gear used in Florida). Therefore, $X_1$, traps per firm, is substituted for $E_2$ and $E_4$. The remaining production factor $E_3$ (capital) is represented by both number of traps per firm and number of firms (measured by number of boats and vessels) $X_2$. Thus $X_2$ is substituted for $E_3$. The biological factors population of mature progeny ($S_1$) and parent population ($S_2$) are not available from secondary data. However both have been shown to be a function of environmental factors, ($S_3$), in the previous chapter. Water temperature is one of the many variables which can be used to represent the environment. Water temperature however has been shown as a significant factor affecting lobster landings (Bell [3]) and thus was used in this study as a proxy for $S_3$ and is denoted as $X_3$. Thus with these assumptions and substitutions Equation 12 can be rewritten as

$$Q = f(X_1, X_2, X_3) \tag{13}$$

Variables in the reduced form equation for the industry harvest function (Equation 13) are compared to variables in the theoretical harvest function (Equation 7) in Table 1.

The reciprocal form of the yield function was selected because it is consistent with current conditions and regulations in the industry. Management regulations such as minimum size limits, gear restrictions, prohibition of egg stripping and a fishing season are after spawning, insures some maximum level of stock. The reciprocal function allows landings to reach a maximum level but does not allow total production

Table 1. Industry harvest function variables in theoretical model and reduced form, economic study of Florida spiny lobster industry

| Variable In Theoretical Model | | Variable In Reduced Form | |
|---|---|---|---|
| Notation | Definition | Notation | Definition |
| $Y_{BE}$ | bioeconomic yield | Q | total industry landings |
| $E_1$ | land (area of fishing) | -- | |
| $E_2$ | labor | $X_1$ | traps per firm |
| $E_3$ | capital | $X_2$ | number of firms |
| $E_4$ | management | $X_1$ | traps per firm |
| $S_1$ | population of mature progeny | -- | |
| $S_2$ | parent population | -- | |
| $S_3$ | environmental attributes | $X_3$ | surface water temperature |

to decline with additional fishing effort. In addition, the reciprocal function exhibits diminishing marginal returns which is consistent with the stage of production in which firms are expected to operate. The industry harvest yield function can be expressed in reciprocal form as

$$\hat{Q} = \hat{a} + \frac{\hat{\beta}_1}{X_1} + \frac{\hat{\beta}_2}{X_2} + \hat{\beta}_3 X_3 \qquad (14)$$

The industry harvest function is used to determine an estimate of maximum sustainable yield (MSY) to serve as a guideline in developing management programs. Since the reciprocal function only approaches a maximum, the MSY analysis considers "approximate" or "practical" maxima. These maxima are estimated using various combinations of explanatory

variables at reasonable maximum levels within the range of the data to determine a range for MSY.

Maximum economic yield (MEY) for the industry was also determined from the industry harvest function (Equation 14). Total revenue (TR) was computed by multiplying the estimated harvest function (Equation 14) by product price ($P_y$). $P_y$ is assumed constant and representative of current prices. $P_y$ was computed as the current average ex-vessel price per pound [1] Time-series cost data were unavailable To determine MEY it was necessary to develop an industry cost function from primary data A cross-sectional survey of spiny lobster firms was used to obtain the necessary data and is presented in a later section. From these data an industry total cost function was developed. Total industry cost (TC) was derived by computing the average total cost per firm (ATC) for the firms in the sample and then multiplying ATC per firm by the total number of firms (N) in the industry. Together, these functions were used to determine MEY as shown in Figure 5.

Derivation of MEY begins with the determination of the level of firms[2] at which the slopes of the TR and TC curves (Figure 5) are equal. This is determined by equating industry marginal revenue (partial derivative of TR with respect to $X_2$) with industry marginal cost (derivative of TC with respect to $X_2$) and then solving for the number of

---

[1] $P_y$ was computed by dividing annual total industry value of landings by annual total industry landings.

[2] An input that serves as a policy variable for management purposes is applicable in place of firms. Number of firms is preferred for reasons to be later discussed in this section

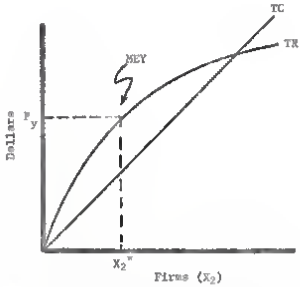


Figure 5. Maximum economic yield (MEY) for the industry is illustrated as the greatest distance between industry total revenue (TR) and industry total cost (TC) with respect to number of firms

firms in the industry which is necessary for industry profit maximization, $X_2^*$.[1] The optimum number of firms, $X_2^*$, is substituted into the industry harvest function to determine $Q^*$, defined as MEY

## Firm Analysis

The primary purposes of the cross-sectional survey and subsequent firm analyses were to (a) provide cost estimates required to determine MEY, (b) determine an optimum allocation of specified inputs for profit

[1]Mathematically the derivation of $X_2^*$ is a solution of the following equalities

(a) industry marginal revenue = industry marginal cost,

(b) $\frac{\partial TR}{\partial X_2} = \frac{\partial TC}{\partial X_2}$, and

(c) $P_y \cdot \frac{\partial Y}{\partial X_2} = P_{X_2}$ is price of $X_2$.

maximization [illegible] the analysis of optimum firm input levels [illegible] the MEY analysis and related analysis of management alternatives.

The firm harvest function is defined as the physical relationship between landings and various units of effort. Effort may be generally categorized as related to labor, capital, management, and fishing area or location (geographical locations). From Equation 11, the general theoretical harvest function, the typical firm harvest function can be defined as

$$q = f(e_1, e_2, e_3, e_4, s_1, s_2, s_3) \tag{15}$$

where,

$q$ = quantity harvested by the typical firm,

$e_1$ = attributes of the fishing process related to fishing area (somewhat similar to land factor input),[1]

$e_2$ = labor,

$e_3$ = capital,

$e_4$ = management,

$s_1$ = mature progeny,

$s_2$ = parent population, and

$s_3$ = environmental attributes.

Environmental and biological influences within a given area were assumed constant for this analysis, since the data represent the lobster harvesting process at a given period in time. Thus, $e_1$, $e_2$, and $e_3$ were deleted

---

[1]Strictly speaking returns to land are to "ownership" of the resource and has little relevance to geographical location in most instances. Returns to area in fishing is similar to saying a type of soil is better than another in reference to agricultural production, which has no relationship with "ownership" of the various soil types.

from Equation 15, except that environmental and biological [illegible] among fishing areas were represented by the coefficient for $e_1$. The objective of this analysis was to determine differences in $e_1$ [illegible] $e_4$ among firms that influence individual firm landings and thus, production responses to different levels of input use. A detailed summary of definitions and derivations of variables that significantly influence the typical firm harvesting process are presented in Appendix D.

A trap is defined as before to represent the unit of effort through which the traditional factors of production are employed in the production process. Thus traps, $x_1$, was substituted for $e_2$, $e_3$, and $e_4$ in Equation 15. In addition, the intensity at which the trap is fished was included in the model through the inclusion of $x_2$ (number of times a fisherman pulls his total number of traps in one week) and $x_3$ (the number of weeks fished). These intensity variables adjusted trap use between firms in a cross-sectional survey and in addition represented additional use of traditional production variables such as labor and capital. Variation in firm size and capital investment were included by a proxy variable, $x_4$, defined to be the square footage of the boat or vessel.

Quality of fishing grounds with respect to stock and other environmental attributes is expected to raise or lower firm harvest and therefore, were entered into the model using dummy variables. Fishing grounds were broadly segregated into three different areas defined by the sample stratification. The upper Keys region ($x_5$) was defined as the 44-miles from Key Largo to Lower Matecumbe Key. The lower Keys region ($x_6$) was defined as that 31-miles from Big Pine Key to Key West. The middle Keys region, the base region, was defined as the 37-mile

stretch between the above two areas. If a one is entered for $x_5$ and a zero for $x_6$ the firm was fishing in the upper keys region and vice-versa for a firm fishing in the lower keys region. If both $x_5$ and $x_6$ are zeros, the firm was fishing in the middle keys region. These dummy variables allow the intercept or position of the harvest function to vary for different fishing areas.

Underlying bioeconomic theory for the firm does not specify curvilinearity in the firm harvest function since the stock of lobsters, or sustainable yield, is assumed constant for a given period in time. Thus the Cobb-Douglas functional form was selected which allows for either increasing, constant, or decreasing returns.[1] An additional reason for the selection of the Cobb-Douglas form was that it requires fewer degrees of freedom to derive the interactive effect among the independent variables. The summary of these considerations and the final model for estimation is represented by Equation 16

$$\hat{q} = \alpha x_1^{\hat{\beta}_1} x_2^{\hat{\beta}_2} x_3^{\hat{\beta}_3} x_4^{\hat{\beta}_4} x_5^{\hat{\beta}_5} x_6^{\hat{\beta}_6} \tag{16}$$

where,

$\hat{q}$ = estimated landings (harvest) for the typical firm,

$x_1$ = number of traps,

$x_2$ = average number of times a fisherman pulls his total number of traps in one week,

$x_3$ = number of weeks fished,

$x_4$ = measure of craft size,

---

[1]A detailed discussion of the Cobb-Douglas function is presented in Carlson [13].

$x_5$ = dummy variable representing upper Keys region (one represents upper Keys and zero represents middle Keys),

$x_6$ = dummy variable representing lower Keys region (one represents lower Keys and zero represents middle Keys), and

$\hat{\alpha}, \hat{\beta}_1, \ldots, \hat{\beta}_6$ are parameters to be estimated

Optimum levels of inputs were determine at the point of profit maximization for the typical firm. The same computational procedure used in the time-series analysis was used to derive TR and TC for the firm and optimal level of input use.

Maximum Economic Analysis (MEY)

The final part of the estimation procedure involved integrating information obtained in the cross-sectional analysis into the time-series model which estimated the industry harvest function. This was then used to estimate maximum economic yield (MEY).

A recognized short-coming of the industry harvest function model is that the assumption of homogeneity among fishing firms or "fishing effort" does not prevail in the real world. Firms differ in fishing power due to such factors as size of craft, fishing intensity, and amount of gear. However, note that Equation 16 representing the firm harvest function and based on cross-sectional data adjusted for these differences. Size of craft was accounted for by $x_4$, fishing intensity by $x_2$ and $x_3$, and amount of gear by $x_1$. With these adjustments it was assumed that the firms were homogeneous. The dummy variables, $x_5$ and $x_6$, further influenced this conclusion.

Estimation of the effect of traps on landings for the typical firm using the firm harvest function took into consideration influences of craft size, ($x_4$), fishing intensity ($x_2$ and $x_3$) and differences in fishing grounds ($x_5$ and $x_6$). With this estimate an analysis of optimum number of traps ($x_1^*$) was made. Then holding trap levels at this economic optimum an estimate of the optimum number of firms was possible. Thus, $x_1^*$ from the cross-sectional fire analysis was substituted for $X_1$ in the time-series industry harvest function model to estimate industry landings assuming firms are employing the optimum number of traps. Equivalent notational form for the industry harvest function now became

$$\hat{Q} = \hat{\alpha} + \frac{\hat{\beta}_1}{x_1^*} + \frac{\hat{\beta}_2}{X_2} + \hat{\beta}_3 X_3 \qquad (17)$$

where,

$\hat{Q}$ = estimated industry landings,

$x_1^*$ = optimal number of traps per firm estimated from firm analysis,

$X_2$ = number of firms in the industry,

$X_3$ = mean seasonal surface water temperature,

$\hat{\alpha}$, $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$ are parameters to be estimated.

MEY with respect to number of firms occurs at that point less than MSY where the difference between total industry revenue and total industry cost are maximized. After deriving industry total revenue and total cost curves, their slopes were equated and the solution for the optimal number of firms ($X_2^*$) was determined. $X_2^*$ occurred when industry marginal revenue equals industry marginal cost of an additional firm. $X_2^*$ was then substituted into the industry harvest function (Equation 17)

and the solution of Q was equal to MEY with respect to $X_2$ for a given level of $X_1$, $X_2$, and $X_3$, expressed as follows:

$$MEY = \hat{Q} = \hat{\alpha} + \frac{\hat{\beta}_1}{X_1^*} + \frac{\hat{\beta}_2}{X_2^*} + \beta_3 X_3 \qquad (18)$$

Thus, traps per firm, estimated from the firm analysis was used as the constant exogenous variable to characterize firms in the industry harvest function model. Ordinarily least squares regression techniques were used to estimate the parameters.

## Study Area and Data Acquisition

The Florida spiny lobster fishery primarily consists of the area known as the Florida Keys region. This region is made up of two counties (Dade and Monroe) and is located in the southernmost portion of the state. Spiny lobsters are landed in small amounts in other counties, mostly Pinellas, but these are usually caught in foreign waters.

Monroe County was selected for the study area for several reasons. A trend analysis of the Florida spiny lobster fishery was conducted using secondary data for 1952-71 (Williams and Prochaska [54]). From this analysis the Florida landings were estimated to be approximately 95 percent of total U.S. landings in recent years. Approximately 50-60 percent in the last five years of Florida landings were caught in foreign waters (Appendix E). The majority (over 90 percent of these foreign lobsters) were landed in Dade County. Of the remaining 40-50 percent of total Florida landings (which came from domestic waters) approximately 80-90 percent were landed in Monroe County (Appendix F). Monroe County is geographically located in the middle of the domestic spiny lobster fishery (Figure 5). A final consideration is that the impact of confining

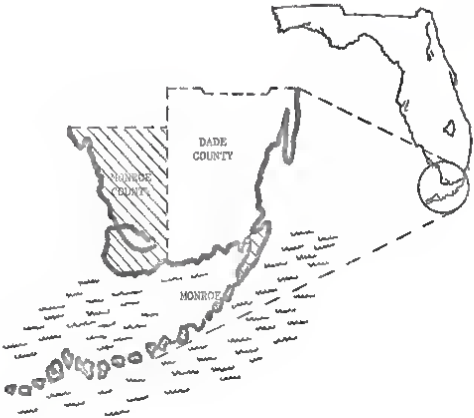


Figure 6 The Florida spiny lobster fishery

all domestic spiny lobster fishermen to the Keys region can be addressed.[1] For these reasons the study area was delineated to include only Monroe County. In addition, it is realistic to include only that area of the fishery over which the state of Florida has jurisdiction since one of the ultimate objectives is to consider management alternatives.

[1] At the time of this final writing the Bahamian government was proposing to limit its fishing grounds to only its citizens. This will mean that future Florida landings will be made up almost exclusively of domestic stock.

Department of [illegible] secondary data on landings, total value of landings, and effort for 1963-73 were used for the time-series analysis [18], [49]. Measures of effort for the industry during this period were total number of traps, total number of vessels, total number of boats; total number of fishermen classified as, on vessels or casual; and total gross tonnage of vessels in the industry. Gross tonnage was measured only for vessels greater than 5 gross tons and was loosely defined as a measure relating to the net capacity of the craft. Water surface temperature data was acquired from Ocean Survey Branch of NOAA [52]. It was assumed that surface water temperature and bottom water temperature vary in proportion in this study. This assumption was based on findings from a study by Robinson [39] that concluded no thermoclines exist, or the water is isothermal in the delineated study area. Temperature data for the study period was in the form of mean, minimum and maximum monthly temperatures for three stations located at South Miami, Marathon, and Key West.

Sample Selection and Size

A sample of the population was drawn since surveying the total population was impractical from a cost and time standpoint. Sample size was determined using the following formula[1]

$$n = \frac{NS^2}{(N - 1) D + S^2} \tag{19}$$

where,

n = sample size,

---

[1] This formula was obtained from Mendenhall [33].

$N$ = population size,

$S^2$ = estimate of the population variance,

$D$ = $M^2/4$, and

$M$ = bound on the error of estimation (i.e., 10 percent on each side).

Data from a sample of 15 observations on 1973-74 landings by individual boats (9) and vessels (6) for sizes ranging from 26 feet to 40 feet in length were obtained for estimating the population variance ($S^2$) [51]. The sample was classified into six vessels and nine boats. $S^2$, a pooled variance (within craft class) was estimated from the actual survey data to be 30,129,877.77. $S$ was selected at 10 percent on each side of the population mean to be estimated. $N$ was equal to 226 and was calculated from a list of commercial craft registrations provided by the Florida State Department of Natural Resources. Criteria used to include a firm in the population was (a) that the address of the craft owner be Monroe County, and (b) that lobster fishing was listed as the primary (dollar value) species harvested. A major limitation of this sampling technique was that fishermen may live out of the county and fish in the study area and vice-versa. Sample size, $N$, was calculated to be 21.

Stratification of the sample was based on length of craft and locations of home port. Proportions in each sample strata were equal to proportions of the population in each strata. Boat length strata were less than 21 feet, 21-30 feet, 31-40 feet, and greater than 40 feet. In the stratification of the study area upper Keys was defined as that area from Key Largo to Lower Matecumbe Key. Middle Keys was defined as that area from Craig Key to Bahia Honda Key and lower Keys was the area from Big Pine Key to Key West. Based on the population as stratified

in Table 2, the following stratified sample illustrated in Table 3 was drawn. Total number of samples drawn was 25 rather than the required 21 in order to round the desired number of samples to whole numbers after stratification.

Table 2. Stratified population of boats and vessels, defined as firms, economic study of Florida spiny lobster industry

| Area | Length (feet) | | | | |
|---|---|---|---|---|---|
| | <21 | 21-30 | 31-40 | >40 | Total |
| Upper Keys | 8 | 28 | 6 | 2 | 44 |
| Middle Keys | 33 | 33 | 14 | 10 | 90 |
| Lower Keys | 37 | 25 | 18 | 9 | 89 |
| TOTAL | 78 | 86 | 38 | 21 | 223 |
| | (35%) | (39%) | (17%) | (9%) | (100%) |

Table 3. Stratified sample of boats and vessels, defined as firms, economic study of Florida spiny lobster industry

| Area | Length (feet) | | | | |
|---|---|---|---|---|---|
| | <21 | 21-30 | 31-40 | >40 | Total |
| Upper Keys | 2 | 2 | 2 | 0 | 6 |
| Middle Keys | 3 | 3 | 2 | 1 | 9 |
| Lower Keys | 3 | 3 | 3 | 1 | 10 |
| TOTAL | 8 | 8 | 7 | 2 | 25 |

The following formula was used to determine the number of observations to be sampled in each stratum:

$$N_{ij} = \frac{C_i}{N} \cdot \frac{C_{ij}}{N} \cdot n \qquad (20)$$

where,

$N_{lj}$ = sample size of strata lj,

$c_l$ = number of craft of length class l,

$c_{lj}$ = number of craft of length class l in area j,

$n$ = total sample size to be drawn, and

$N$ = total population of craft

Survey Technique

Observational units within each strata were not drawn randomly in the usual sense. The data were collected in a very precarious environment, at a very difficult time. Florida spiny lobster fishermen, like most fishermen, are very independent and generally do not divulge information. So, there was first a problem of locating a fisherman that would cooperate. A second problem frequently encountered was that many cooperative fishermen lacked adequate records, particularly costs, so much of the information was "best estimates." To complicate the matter, at the time of the survey the Internal Revenue Service was investigating Florida fishermen because a recent court ruling had changed the tax regulation, retroactively, and thus information was highly guarded. Also it was felt by many that a substantial amount of underreported lobster were "blackmarketed" from this area. In addition, any list of fishermen was usually out of date because of the highly mobile nature of fishermen. Given these circumstances, it was impossible to collect data on a strictly random basis. Thus, the samples represent fishermen who would cooperate. Personal interviews were conducted until the required number of observations within each strata was accomplished.

Initial fisherman contacts were acquired through the Southeastern Fisheries Center in Miami and a local chapter of Organized Fishermen of Florida (O.F.F.)[1] In July 1974 the research project was presented and a questionnaire pretested at a local O.F.F. Chapter meeting in the area. Possible benefits to the fishermen were explained as well as soliciting their cooperation for interviews to be conducted in the fall. Also, names of fishhouse managers that would cooperate in encouraging their local lobster fishermen to be interviewed were obtained.

In October 1974 the interviewing began using a thirteen page questionnaire with those fishermen that agreed to cooperate the past July.[2] Once this source of interviews was exhausted, various cooperating fishhouses were then contacted. Managers were asked to recommend fishermen that they felt would cooperate and that were needed to complete the various strata as specified by the sample design. Interviewing continued for three weeks until all observations required in the sample as stratified were collected. Twenty-eight questionnaires were completed and after editing for inconsistencies and incompleteness, twenty-five were used in the analysis. Additional observations were collected for those strata that were weighted heaviest to ensure completeness. Data comparisons of study projections with industry output characteristics suggest the sample was representative.

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[1]The author is indebted to Mr. Lloyd Johnson and Mr. Pete Maicy, agents of the Southeastern Fisheries Center, NOAA, NMFS, and the officers of the Lower Keys Chapter of O.F.F. located in the Summerland Key area.

[2]Appendix J includes the survey questionnaire.

## CHAPTER V

## ANALYSIS OF RESULTS

Estimated coefficients and their interpretation for the industry and firms' harvest functions are presented in this chapter. Information from the industry harvest model was used to derive estimates of MSY and MEY. Optimum input levels and related costs at current stock levels for the "typical" firm were derived from the firm harvest model. Information obtained from both analyses was then integrated to analyze alternative fishing practices.

### Bioeconomic Model

As previously mentioned, the reciprocal function was selected for the time-series estimation because of its theoretical characteristics and its simplicity. Recall that current management programs such as size limits and protection of berried females suggested the model to be realistic. The management program protects the young until they reach minimum size. Thus, assuming continuous fishing pressure it is possible that (a) there is a level of pounds landed which is a function of the weight of minimum-sized lobsters and (b) increased effort alone will not cause total landing to decrease because of present size and sex regulations.

The reciprocal function allows landings to reach a maximum limit but does not allow total landings to decrease with increased effort.

it also allows decreasing marginal returns to fishing effort.[1]

The following spiny lobster harvest function is the statistical model estimated using time-series data.

$$\hat{Q} = \hat{a} + \hat{\beta}_1 \frac{1}{X_1} + \hat{\beta}_2 \frac{1}{X_2} + \hat{\beta}_3 X_3 + e. \tag{21}$$

The estimated coefficients and standard errors are presented in Equation (22).

$$Q = \underset{}{28{,}379{,}136} - \underset{(365{,}878{,}684)}{1{,}439{,}976{,}169} \frac{1}{X_1} - \underset{(216{,}457{,}337)}{465{,}173{,}997} \frac{1}{X_2} - \underset{(170{,}321)}{239{,}791} X_3 \tag{22}$$

Overall the model was statistically significant at the .01 level ($F_{3,7} = 9.16$). The coefficient of determination, $R^2$ and $\bar{R}^2$ (which was $R^2$ corrected for degrees of freedom) indicated that the model explained 80 and 75 percent of the variation in annual landings, respectively. A Durbin-Watson value of 2.38 indicated the model hinges on the border between no autocorrelation and inconclusiveness range of the test.[2] The coefficients for traps per firm, $\hat{\beta}_1$, and number of firms traps in the industry, $\hat{\beta}_2$, were found to be statistically different from zero at the .01 and .07 levels of significance, respectively.

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[1] As a check on the logic of using the reciprocal form of the function other functions were considered, but none of these yielded "better" results. For the second degree polynomial function, negative signs were estimated for the parameters but the coefficients estimated were not significantly different from zero.

[2] Durbin-Watson statistic is not calculated for less than 15 observations. Therefore DW was not used to test in this case. However, there was no apparent pattern of the residuals.

Observed and predicted values of landings for 1963-73 are shown in Figure 7. Since 1969, landings have varied between 4 and 5 million pounds, with a slight exception in 1970. Maximum landings observed within the data range occurred in 1970 at 5.24 million pounds. In 1973 landings decreased to 4.99 million pounds. Assuming current management regulations are adequate and new technology does not occur, there is little reason to expect landings to increase substantially above five or six million pounds annually. This assumes that biological and environmental factors will remain substantially unchanged.

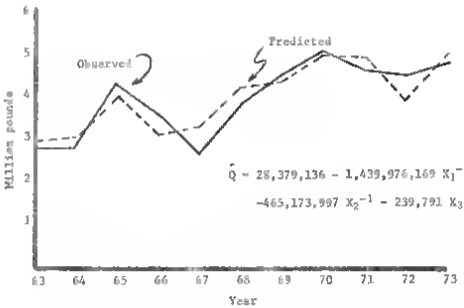


Figure 7. Observed and predicted volume of spiny lobster landings, 1963-73 for Monroe County, Florida

The marginal effect of changes in effort on landings was determined by the partial derivatives of the bioeconomic industry harvest function (Equation 22) with respect to the specific explanatory variable measuring effort. The following marginal products ($MP_{X_i}$) of the harvest function are partial derivatives with respect to a given explanatory variable, $X_i$:

$$MP_{X_1} = \frac{\partial Q}{\partial X_1} = -\frac{\hat{\beta}_1}{X_1^2} = \frac{1,439,976,169}{X_1^2} \tag{23}$$

$$MP_{X_2} = \frac{\partial Q}{\partial X_2} = -\frac{\hat{\beta}_2}{X_2^2} = \frac{465,173,997}{X_2^2} \tag{24}$$

$$MP_{X_3} = \frac{\partial Q}{\partial X_3} = \hat{\beta}_3 = -239,791 \tag{25}$$

The additional pounds of lobsters landed in the industry when each firm intensifies production by adding one trap is shown by $MP_{X_1}$. As each firm adds a trap total landings increase at a decreasing rate. The additional catch per firm can be calculated by $\frac{MP_{X_1}}{X_2}$ for each $MP_{X_1}$. Additional catch per firm is simply the $MP_{X_2}$ divided by $X_2$. $MP_{X_2}$ is also a declining function of the number of firms in the industry and is interpreted to be the additional industry landings resulting from adding one additional firm to the industry with the same characteristics as all other firms in the industry.

In the empirical analysis of specific marginal products numerical values of other variables were held constant at their mean levels. Traps per firm ($X_1$) and number of firms ($X_2$) were held constant at 429 traps per firm and 399 firms, respectively. Mean seasonal surface water

temperature was 77.591°F. Evaluating $MP_{X_1}$ (Equation 23) at 1973 input levels gives

$$MP_{X_1} = \frac{1,439,976,169}{(429)^2} = 7,824 \text{ pounds.} \tag{26}$$

As each firm in the industry increases the number of traps it fishes by one, total landings for the industry increases by 7,824 pounds. A one trap increase per firm is equivalent to a 399 total trap increase for the industry and an increase of 19.59 pounds per trap.

Evaluating the effect of changing the number of firms in the industry (Equation 24) gives

$$MP_{X_2} = \frac{465,173,997}{(399)^2} = 2,922 \text{ pounds.} \tag{27}$$

Holding traps per firm and water temperature constant and increasing the number of firms by one increases total industry landings by 2,922 pounds. Increasing the number of firms by one unit and holding traps per firm constant, brings 429 new traps into the industry. The fishing power of an additional trap to the industry may be greater if it is the first trap for a new firm compared to an additional trap for a firm already fishing. However, the marginal analysis as set forth will not allow for this difference.

Evaluating the effect of changes in water temperature (Equation 25) gives

$$MP_{X_3} = \hat{\beta}_3 = -239,791 \text{ pounds} \tag{28}$$

For every one degree increase in the mean surface water temperature for the season, total industry landings will decrease by 239,791 pounds or about 5 percent of total landings in 1973. A general consensus among fishermen is that landings increase shortly after meteorological

changes such as storms and weather fronts. These weather changes often create lower temperatures and partially explain the inverse relationship of this parameter.

Maximum Sustainable Yield (MSY) Estimate

One of the initial objectives in this study was to address the question of "the status of the spiny lobster fishery with respect to maximum sustainable yield (MSY)." The industry bioeconomic harvest model indicated that industry landings are approaching a maximum sustainable yield. The bioeconomic empirical model based on a theoretical curvilinear harvest function fitted the data very well ($\bar{R}^2 = .75$). Explanatory variables were individually highly significant and the total "accounted for" variation was significant. At current levels of effort the percentage increase in landings was much less than the percentage increases in inputs.

These conclusions were reached observing the range in landings as inputs were increased to an infinitely large number as shown in Table 4. Inputs were held constant at 1973 mean values while the remaining variables were varied. Landings were also analyzed with seasonal water temperature ($X_3$) which was held constant at its mean, minimum, and maximum observed values.

The range of maximum landings was from 5.9 million to 8.9 million pounds. Illustrated in Figure 8 is the harvest function as it reaches a maximum of 7.89 million pounds with 2,000 traps per firm ($X_1$), holding total number of firms ($X_2$) at the 1973 level of 399 and seasonal water temperature ($X_3$) at its mean of 77.59. Although some fishermen are fishing 2,000 traps, this number was chosen to illustrate the approximate

Table 4. Estimated levels of maximum landings (Q) for given levels of traps per firm ($X_1$), number of firms ($X_2$), and seasonal water temperature ($X_3$), economic study of Florida spiny lobster industry

| Maximum landings (Q) | Variable approaching ∞ (infinity) | Level of Variables Held Constant | | |
|---|---|---|---|---|
| | | $X_1$ | $X_2$ | $X_3$ |
| 8,152,905 | $X_1$ | -- | 287 (MEAN) | 77.59 (MEAN) |
| 8,607,871 | $X_1$ | -- | 399 (MAX, 1973) | 77.59 (MEAN) |
| 8,121,094 | $X_1$ | -- | 399 (MAX, 1973) | 79.62 (MAX, 1972) |
| 8,450,247 | $X_1$ | -- | 287 (MEAN) | 76.35 (MIN, 1969) |
| 8,905,212 | $X_1$ | -- | 399 (MAX, 1973) | 76.35 (MIN, 1969) |
| 7,666,129 | $X_1$ | -- | 287 (MEAN) | 79.62 (MAX, 1972) |
| 5,860,742 | $X_2$ | 368 (MEAN) | — | 77.59 (MEAN) |
| 6,416,893 | $X_2$ | 429 (1973) | — | 77.59 (MEAN) |
| 6,786,218 | $X_2$ | 482 (MAX, 1971) | — | 77.59 (MEAN) |
| 6,295,442 | $X_2$ | 482 (MAX, 1971) | — | 79.62 (MAX, 1972) |
| 7,083,559 | $X_2$ | 482 (MAX, 1971) | — | 76.35 (MIN, 1969) |

Note: Mean, minimum, and maximum refer to values for Monroe County time series data, 1962-73 (Appendix A). Numbers in parentheses represent year.

point where the bioeconomic harvest function becomes flat for all practical purposes. This represents a 366 percent increase in traps per firm and a 58 percent increase in landings. Note that the levels of inputs required to achieve the maximum output levels in Table 4 were totally unrealistic at levels of infinity. A 18 to 78 percent increase

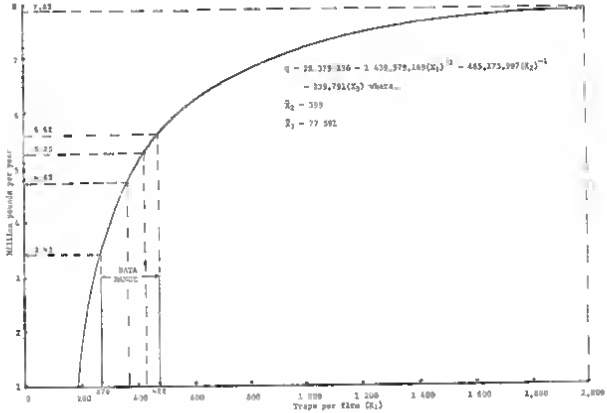


Figure 8 Spiny lobster bioeconomic industry harvest function

in landings would require an infinite percentage increase in inputs. The same point is illustrated in Figure 8 but traps per firm is presented in a more realistic range. Predicted landings increase by 40 percent, from 5.62 to 7.88 million pounds, as a result of a 115 percent increase in the number of traps per firm (from the maximum observed in the data of 482 to 2,000).

Estimates of MSY chosen for analysis in this study ranged between six million and eight million pounds with a realistic estimate probably in the range of six to seven million pounds. This is not to imply that landings cannot increase above these figures, but rather that these figures are the levels estimated at which landings could be maintained from year to year--maximum sustainable harvest (yield), ceteris paribus. Actually, the limiting factor probably is that the typical firm does not have the capacity to reach the required trap level.

In summary, maximum harvest levels considered here are quite liberal for several reasons. Some illustrations used extremely unrealistic levels of inputs to achieve the maximum levels of harvest and more importantly, some input levels were beyond the range of data. Estimated landings may be beyond maximum economic yield, discussed in the next section. In addition, substantial input increases of this nature may cause irreversible effects on the population, not directly observable in the existing data on which the analysis was based. Therefore, the realistic MSY level was concluded to be in the range of six to seven million pounds annually.

## Value Marginal Product Analysis

A more comprehensive analysis of maximum economic yield (MEY) is presented in the section integrating results from the cross-sectional

and time-series analyses, but some knowledge of levels of expenditures and profit maximization can be gained using results of the time-series industry analysis thus far.

Value marginal products for given inputs were derived by multiplying constant product price times the respective marginal physical product. The value marginal product equation for traps per firm ($X_1$) is[1]

$$VMP_{X_1} = P_y \cdot MP_{X_1} = P_y\left(-\frac{\hat{B}_1}{X_1^2}\right) \qquad (29)$$

where,

$P_y$ = annual average dockside price per pound of lobster, assumed constant,

$-\frac{\hat{B}_1}{X_1^2}$ = marginal product of Q with respect to input $X_1$ (Equation 23).

$VMP_{X_1}$ is the addition to industry total revenue as a result of a marginal increase in traps fished per firm. $VMP_{X_1}$ was divided by the number of firms in the industry in 1973 (399) to demonstrate the effect of price changes on an individual firm (Figure 9)

Product prices per pound used in the analysis were $1.08,[2] $1.25, $1.50, and $2.00. In this price range the value marginal product ranged from approximately $4.81 to $140.00 on traps per firm vary from approximately 900 to 168, respectively. At a product price of $1.08 and traps per firm at the mean level for 1952-71 (368) the $VMP_{X_1}$ was $28.77. If the cost for an additional trap were $28.77, this would be the profit

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[1] VMP is with respect to the subscript ($x_1$) denoted in Equation 29.

[2] Mean ex-vessel price of $1.08 per pound was obtained from a survey of 25 lobster boat captains taken in 1973.

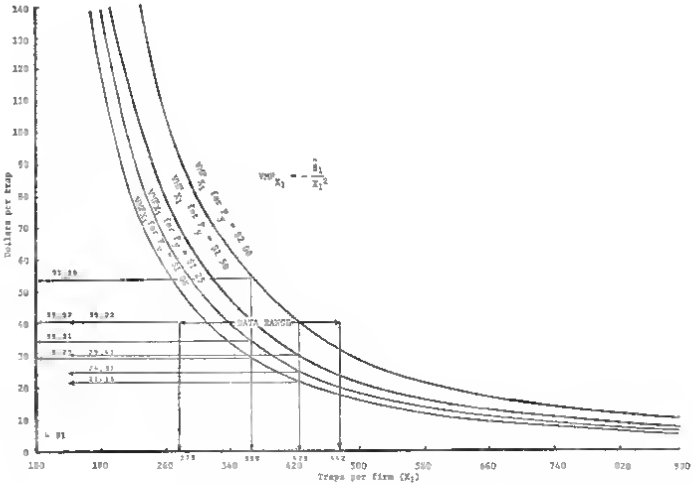


Figure 9. Value marginal product of traps per firm ($X_1$) divided by the maximum number of firms observed (399) in the industry in 1973

maximization level of output. Thus as long as the cost of fishing a trap was less than $28 77 it would pay to expand.[1] At dockside prices of $1.25, $1.50, and $2 00, marginal cost per trap could increase to $33 31, $39 97, and $53 30, respectively, before the input level for profit maximization would be reached. With traps per firm ($X_1$) at the 1973 level of 429, $VMP_{X_1}$ ranged from $21 16 (assuming a product price of $1 08 per pound) to $39 22 (assuming a product price of $2 00 per pound). Maximum level of traps per firm observed was 482 in 1971. At this level $VMP_{X_1}$ ranged from $16 77 to $31.07 for product prices ranging from $1.08 to $2.00 per pound. These values exceed trap costs and encourage intensification of traps fished per fisherman.

Value marginal product for an additional firm was also analyzed while holding traps per firm ($X_1$) constant. Value marginal product for the firm was expressed as

$$VMP_{X_2} = P_y\left(-\frac{\hat{\beta}_2}{X_2^2}\right) \tag{30}$$

where,

$-\frac{\hat{\beta}_2}{X_2^2}$ = marginal product of Q (Equation 24) with respect to firms ($X_2$), holding $X_1$ constant.

Estimates of $VMP_{X_2}$ for the mean, minimum, maximum, and 1973 levels of firms are presented in Figure 10 at the product prices used earlier. Profit maximization will occur with 389 firms in the industry when the total cost for the typical firm reaches $3,154, $3,652, $4,383, or $5,844, given product prices of $1 08, $1 25, $1 50, or $2 00, respectively.

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[1]Cost of an additional trap includes fixed costs for construction and craft, and variable expenses incurred to fish the trap such as fuel, bait, and labor.

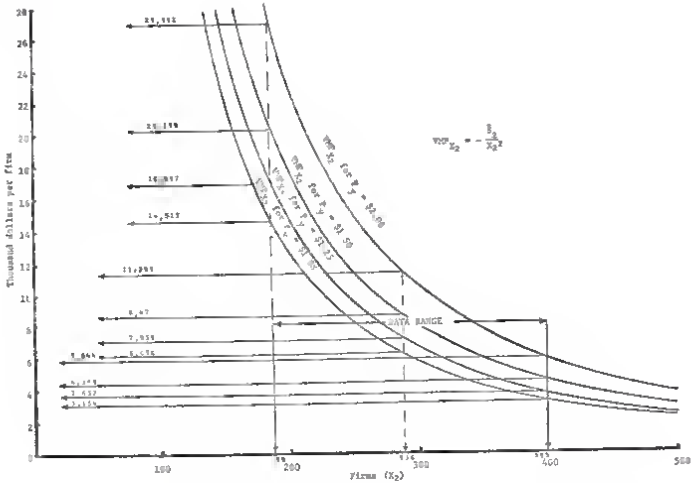


Figure 10. Value marginal product of firms ($X_2$)

respectively (Equation 30, Figure 10). The difference between industry total value of landings in 1973 for 399 firms fishing compared with 400 firms fishing was $3,154 at a product price of $1.08. In order to generate a net profit to the industry, the addition to industry total cost from the 400th firm fishing must be less than $3,154.

## Analysis of Firm Harvest Function Model

Time-series data on firms included both part-time and full-time commercial fishermen. Some of these firms fish in more productive fishing grounds than others which can significantly influence the firm harvest rate. Fishing power and intensity of this power varies substantially between firms which influences the firm harvest rate. Aggregate data measuring explanatory variables such as firms and traps have all of these production input differences confounded in their estimated effects, thus making the interpretation of estimated coefficients very difficult and incomplete. Therefore, one objective of the cross-sectional analysis was to obtain partial estimates adjusted for these other influences. A second objective was to develop cost estimates which would be used with the time-series bioeconomic model to determine maximum economic yield for given measures of effort. That analysis is presented in this section along with a brief analysis of optimum resource allocation for the firm at a given fishery stock level.

## Firm Harvest Model

The harvesting process for the typical spiny lobster firm was estimated using a Cobb-Douglas functional form. The empirical data must lie in Stage II of production since diminishing marginal returns are indicated by less than unity values estimated for the parameters. The

estimated equation is

$$\hat{q} = 4.09000\, x_1^{.7577}\, x_2^{.4359}\, x_3^{.37211}\, x_4^{.30876}\, x_5^{.44455}\, x_6^{.13063} \qquad (31)$$

Equation 31 was estimated in log linear form using ordinary least square methods. This entails minimizing the sum of squares of the logarithms of residuals. The assumptions of BLUE estimators are still valid.

Landings per firm (q) were measured in pounds. Average traps fished per firm ($x_1$) was a weighted average of traps fished per firm. This variable considered the initial number of traps fished at the beginning of the season, the number of traps lost during each month of the season, and the number of times a trap was fished before lost. Rounds per week ($x_2$) was a measure of effort intensity and was defined as the season average proportion of traps pulled per week for the season. A round was defined as a single pulling of all traps. Total number of weeks fished ($x_3$) was another measure of effort intensity. In Florida a maximum of 36 weeks is allowed in the season by law. Fishing power of the firm ($x_4$) was taken into consideration by including a size variable. The square area of the hull was used as a proxy for size. Influences on harvest levels due to quality differences in fishing grounds were accounted for by including dummy variables $x_5$ and $x_6$ which broadly characterized the firms into the three areas previously defined.[1]

The $\bar{R}^2$ corrected for small sample size showed that the harvest function explained 82 percent of the variation in a typical firm's

[1]Derivations and detailed definitions of the explanatory variables are presented in Appendix D. Appendix G contains the estimating equations for landings (q) and marginal products ($MP_{x_i}$). Appendix L contains the data used to estimate the firm harvest $x_i$ function.

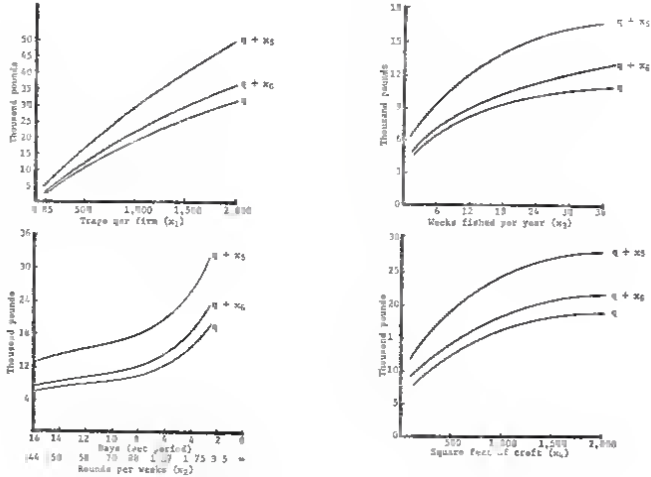


Figure 11, Firm harvest functions with respect to effort measured as gear ($X_1$), fishing intensity ($X_2$, $X_3$), firm size ($X_4$), and adjusted for fishing grounds ($X_5$, $X_6$)

landings (Table 5). The range in error of estimated landings was computed by expressing the antilog of the standard error of the estimate (SEE) as a percentage of the total estimated value. For Equation 31 landings varied from 31.5 percent above to 24.0 percent below the estimated harvest values

Table 5. Regression statistics for the cross-sectional firm harvest functions model, economic study of Florida spiny lobster industry

| Independent Variables ($x_i$) | Estimated Coefficient ($B_i$) | Standard Error | t-Ratio | Significance Level of Probability |
|---|---|---|---|---|
| Constant (a) | 4.09000 | 1.2500 | 1.128 | -- |
| Traps per firm ($x_1$) | .75770 | .1089 | 6.895 | .9999 |
| Hounds per week ($x_2$) | .43991 | .2772 | 1.587 | .8700 |
| Weeks fished ($x_3$) | .37211 | .2400 | 1.550 | .8615 |
| Craft size ($x_4$) | .30876 | .1358 | 2.274 | .9645 |
| Upper Keys area ($x_5$) | .44455 | .1493 | 2.977 | .9919 |
| Lower Keys area ($x_6$) | .13063 | .1653 | .790 | .5603 |

Note: $\bar{R}^2$ = .8223, $R^2$ = .9310, d.f. = 18, SEE = .2742, $F_{6,18}$ = 19.514

The relationship of landings to effort ($x_1$, $x_2$, $x_3$ and $x_4$) for the firm is presented in Figure 11. Adjustments to the firm harvest functions for the influence of different fishing grounds is also illustrated

An analysis of the estimated effort coefficients (Equation 31) indicated that the function is homogeneous of degree 1.87848 and thus defined an industry exhibiting increasing returns to scale. The theoretical interpretation was that the marginal returns to a simultaneous

increase in all inputs was positive and total landings were increasing at an increasing rate. Homogenity of 1.87848 means that if each of the independent variables of the harvest function are multiplied by a constant k, landings will change by a multiple of $k^{1.87848}$. For example, if $x_1 \ldots x_6$ are all doubled (k = 2) landings are more than quadruple. To illustrate the significance of this, assume that the State of Florida determined that MSY had been surpassed and landings would have to be reduced by, say, approximately 50 percent to protect the fishery stock from irreversible damage. Given homogenity of 1.87848, all inputs would have to be reduced by only 25 percent to obtain a 58 percent reduction in landings per firm, and thus, for the industry, assuming homogeneous firms.[1] If the state does not have control over individual effort, individual firms would have to be provided some inducement to voluntarily cut back input usage, similar to the objective of the Federal Soil Bank Program for agriculture in the 1960s. Although this type of analysis may provide some interesting insights into management of the fishery, it may be argued that the interpretation is non-sensical. Realistically speaking, size of craft and number of weeks are definitely limited beyond some point of expansion.

Estimated Parameters

The estimated coefficients ($\hat{\beta}_i$) of the harvest function presented in Table 5 explained the percentage change in landings due to a given one percent change in the particular input level, assuming all other inputs

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[1] Notationally the derivation is as follows

$$(.75)^{1.87848} \cdot q = .58\ q$$

where,

q = firm harvest function (Equation 31)

constant. These were defined as output elasticities and can also be expressed as ratios of marginal and average productivities.

Partial differentiation of the harvest function (Equation 31) with respect to given explanatory variables, gave the marginal products as follows:

$$MP_{x_1} = \frac{\partial q}{\partial x_1} = \hat{\alpha}\,\hat{\beta}_1 x_1^{\hat{\beta}_1 - 1} x_2^{\hat{\beta}_2} x_3^{\hat{\beta}_3} x_4^{\hat{\beta}_4} x_5^{\hat{\beta}_5} x_6^{\hat{\beta}_6} \tag{32}$$

$$MP_{x_2} = \frac{\partial q}{\partial x_2} = \hat{\alpha}\,\hat{\beta}_2 x_2^{\hat{\beta}_2 - 2} x_1^{\hat{\beta}_1} x_3^{\hat{\beta}_3} x_4^{\hat{\beta}_4} x_5^{\hat{\beta}_5} x_6^{\hat{\beta}_6} \tag{33}$$

$$MP_{x_3} = \frac{\partial q}{\partial x_3} = \hat{\alpha}\,\hat{\beta}_3 x_3^{\hat{\beta}_3 - 1} x_1^{\hat{\beta}_1} x_2^{\hat{\beta}_2} x_4^{\hat{\beta}_4} x_5^{\hat{\beta}_5} x_6^{\hat{\beta}_6} \tag{34}$$

$$MP_{x_4} = \frac{\partial q}{\partial x_4} = \hat{\alpha}\,\hat{\beta}_4 x_4^{\hat{\beta}_4 - 1} x_1^{\hat{\beta}_1} x_2^{\hat{\beta}_2} x_3^{\hat{\beta}_3} x_5^{\hat{\beta}_5} x_6^{\hat{\beta}_6} \tag{35}$$

Traps per firm ($x_1$)

The estimated parameter ($\hat{\beta}_1$) is interpreted as a 76 percent increase in landings due to a one percent increase in number of traps for the firm. $\hat{\beta}_1$ is statistically significant at the 99 percent confidence level.[1]

The marginal increase in landings due to the addition of one trap by the typical firm is:

$$MP_{x_1} = 62.85x_1^{-.2423} \tag{36}$$

The derivative of $MP_{x_1}$ was negative implying marginal landings per trap will decrease as additional traps are added by each firm to the total

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[1]Alternatively, the probability of randomly obtaining a $\hat{\beta}$ as large as $\hat{\beta}_1$, if $\beta_1$ is equal to zero is less than .01.

number fished. The marginal return to an additional trap was positive and also greater than the marginal return for any of the other three forms of effort.

Rounds per week ($x_2$)

As the firm increased its trap pulling rate by one percent (i.e., decreases its set period), landings increased by 44 percent ($\hat{\beta}_2 = .43991$). Rounds per week is an index measuring fishing intensity as defined in Appendix D. $\hat{\beta}_2$ was statistically significant at the 87 percent confidence level. The marginal product of $x_2$ was expressed as

$$MP_{x_2} = 5317\ x_2^{-.5681} \tag{37}$$

As $x_2$ increased the rate of increase in landings decreased. For example, assume the firm is pulling all of its traps once per week. The marginal product (Equation 37) of increasing this rate to twice per week would be approximately 4,500 pounds.

Useful information contained in this index is the expected gain in landings due to increasing the number of days a fisherman's traps set between harvest periods.[1] Rounds per week ($x_2$) was computed by dividing the average number of days in a set period for the season into seven days of a week. By substituting this definition for rounds per week into the firm harvest function (Equation 31) the marginal product of increasing the set period an additional day was calculated (Table 6).

For example, a fisherman previously harvesting his traps after the third day can increase his total harvest by 2491 pounds by letting his

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[1] This is often referred to as "set period" among fishermen.

Table 6. Marginal products for various lengths of set periods, economic study of Florida spiny lobster fishery

| Days in set period ($z$) | Increase in landing due to a one day increase in set period ($MP_z$) | Fishing effort intensity in terms of rounds per week ($x_2$) |
|---|---|---|
| 3 | 2491 | 2.333 |
| 7 | 735 | 1.000 |
| 10 | 440 | .700 |
| 14 | 271 | .500 |

traps set four days between harvests. Likewise total landings can be increased by 735 pounds by increasing the set period from 7 days to 8 days. Increasing from a 10 day set period to an eleven day set period would increase total landings by 440 pounds, while a 271 pound increase could be expected by allowing traps to set 15 days instead of 14 days. Marginal increases in total landings due to increasing the set period by one day can be estimated for any length of set period by the following equation:

$$MP_z = 12116\ z^{-1.43991} \tag{38}$$

where,

$MP_z$ is the marginal product due to increasing the set period by one day,

$z$ is the number of days in the set period or between rounds, and

$z = 7/x_2$.

Equivalent levels of fishing effort intensity measured as rounds per week ($x_2$) for the examples shown in Table 6 range from 2.333 rounds per week for fishermen that harvest after a three day set period to .500

rounds per week for fishermen that pull all their traps every two weeks.

Interpretation of these estimates of $MP_{X_2}$ must be treated with care. First, the data represent seasonal mean levels of landings related to rounds per week which vary greatly from week to week throughout the season. During August, the first month of the season, the mean set period for the 25 total firms in the sample was 5.8 days. By March, the last month of the season, the mean was 13.3 days. The March mean was for only 20 of the 25 sample firms since some of the larger, multiple species fishermen usually stop lobster fishing by the end of December.

Although this question was not specifically asked in the interview a considerable amount of information was volunteered that indicated the maximum level of set period, relative to poaching and vandalism, was correlated with location of fishing ground to populated areas, distance from shore, and depth of water. The remarks indicated that approximately four days was the maximum length of time traps could set between harvest periods, particularly at the beginning of the season. This could be extended to six days if either the traps were in sight of land or firms banded together in groups to fish on area several miles from shore.

Weeks fished per season ($X_3$)

Landings increased very rapidly the first few weeks of the season, then leveled off. Recall that in Figure 11 it was shown that approximately 54.5 percent of total landings for the 36-week season are harvested within the first six weeks. This was supported by the estimated output elasticity for weeks. $\hat{\beta}_3$ shows that landings increase .37 percent for a one percent increase in weeks fished. Expected weekly landings

beginning at various dates within the season can be estimated using the marginal product of weeks, expressed as follows:

$$MP_{x_3} = 1093.46\ x_3^{-.6279} \tag{39}$$

The second partial derivative of the harvest function for weeks fished showed $MP_{x_3}$ diminishing at an increasing rate.

$$\frac{\partial^2 q}{\partial x_3^2} = -686.58\ x_3^{-1.6279} \tag{40}$$

Estimated marginal products are presented in Table 7 for various periods throughout the harvest season. $\hat{\beta}_3$ was statistically significant at the 86 percent confidence level.

Table 7. Weekly landings expected for given dates within the spiny lobster season, economic study of Florida spiny lobster industry

| Beginning date of Week | | ($x_3$) Weeks fished | Change in landings for each addition week fished ($MP_{x_3}$) |
|---|---|---|---|
| August | 7 | 1.00 | 1,093 |
| | 14 | 2.00 | 708 |
| | 31 | 4.43 | 429 |
| September | 15 | 6.57 | 335 |
| | 30 | 8.71 | 281 |
| October | 31 | 13.14 | 217 |
| November | 30 | 17.43 | 182 |
| December | 31 | 21.86 | 158 |
| February | 28 | 30.29 | 128 |
| March | 31 | 36.14 | 115 |

An additional week of fishing after August 7 would return approximately 1,093 pounds. By the third and fourth week, landings would drop

off to 708 pounds and then to 429 pounds per week, respectively. After the 1st of September weekly landings tended to level off dropping to less than 200 pounds per week by December 1st. Some of the larger firms with greater capital investments quit lobster fishing by November 1st and go to other species. The expected per returns from netting mackerel or long-living yellowtail snapper are evidently greater for at least these firms. Four out of the 25 firms in the sample did not fish the entire season. At least three of these four were always ranked in the top five in number of traps ($x_1$), fishing intensity ($x_2$), and size of craft ($x_4$). The cost per pound of fishing extra weeks becomes substantial and returns become relatively small. Smaller firms often did not have the alternative of fishing for other species at higher net returns and remained in the lobster fishery the entire season. On the other hand, larger firms have a comparative advantage in other fisheries and began leaving after the 13th week of the season when approximately 68.6 percent of total landings had been harvested.

By changing species early in the harvest season larger firms can reduce costs substantially for several reasons. After two months the trap lines become frayed and traps break off and are lost in hauling.[1] Those traps not lost to frayed buoy lines require additional repairs which reduce the efficiency of the harvesting process. Second, by late summer the probability of ocean storms increases substantially and the risk of losing traps to high winds and rough waters becomes high. Consequently, larger firms fishing in excess of 800 traps have the largest total risk and pull out of trap fishing early in the season in an effort to reduce costs.

[1]Hauling is defined as pulling a trap out of the water.

Craft size ($x_4$)

Craft size, defined as the square area of the hull, was the most significant of several measures developed from characteristics of the craft. It is reasonable to assume that the effect of craft size ($\hat{\beta}_4$) is confounded. There is decreased speed but increased size which allows more traps to be transported and relocated. $\hat{\beta}_4$ was statistically significant at the 97 percent confidence level. From $\hat{\beta}_4$, it was concluded that landings increased .31 percent for each one percent increase in craft size and the marginal product of craft size increased at a decreasing rate. This was the smallest response of all the measures of effort. The range of craft size in the sample was from 80 to 1,045 square feet, while the mean of the sample was 326.88 square feet. Number of craft and hull lengths in each group of the sample were: seven, 16-20 feet; seven, 21-30 feet; seven, 31-40 feet; and four 40-55 feet. Appendix H further elaborates various characteristics and practices classified according to length, for the lobster firms surveyed.

Marginal returns for increases in square footage of the hull ($x_4$) are presented in Table 8 and were estimated using the following equation

$$MP_{x_4} = 558.29\, x_4^{-.69124} \qquad (41)$$

Marginal product ($MP_{x_4}$) due to a foot increase in the hull size ranged from 27.00 pounds for craft 80 square feet in size to 4.57 pounds for craft 675 square feet in size. At levels of $x_4$ less than 350 square feet the marginal product decreased at a greater rate per unit of increase in square footage of hull than for craft greater than 350 square feet. This was determined by the slope of the marginal product curve in Figure 12, being less than zero. This indicated a decreasing rate

Table 8 Marginal products of craft size ($x_4$) for sample sizes observed, economic study of Florida spiny lobster industry

| Craft size ($x_4$) (length x width) | Length | Width | Change in landings for each additional square foot increase in craft size ($MP_{x_4}$) |
|---|---|---|---|
| 80 | 16 | 5 | 27.00 |
| 96 | 16 | 6 | 23.80 |
| 140 | 20 | 7 | 18.34 |
| 154 | 22 | 7 | 17.17 |
| 176 | 22 | 8 | 15.66 |
| 200 | 25 | 8 | 14.33 |
| 208 | 26 | 8 | 13.95 |
| 234 | 26 | 9 | 12.86 |
| 240 | 24 | 10 | 12.63 |
| 252 | 28 | 9 | 12.22 |
| 330 | 33 | 10 | 10.14 |
| 340 | 34 | 10 | 9.53 |
| 341 | 31 | 11 | 9.91 |
| 408 | 34 | 12 | 8.76 |
| 432 | 36 | 12 | 8.41 |
| 468 | 36 | 13 | 7.96 |
| 480 | 40 | 12 | 7.82 |
| 574 | 41 | 14 | 6.91 |
| 675 | 45 | 15 | 6.18 |
| 1045 | 55 | 19 | 4.57 |

of return. After $x_4$ reached 350 square feet (approximately 34 feet long times 10 feet wide) returns to increasing the size of the craft began to level off. For example, in Table 8 marginal product of craft size decreased by 48 percent compared with a 156 percent increase in craft size, as the square footage increased from 408 (34 feet x 12 feet) to 1,045 (55 feet x 19 feet). The implications were that marginal decreases in landings due to increases in the size of the craft were smaller for larger firms than for smaller firms at mean levels of various inputs.

In summary, the estimated firm harvest model fitted the data well and all individual exploratory variables were highly significant statistically. The model indicated that firms were operating in stage II of

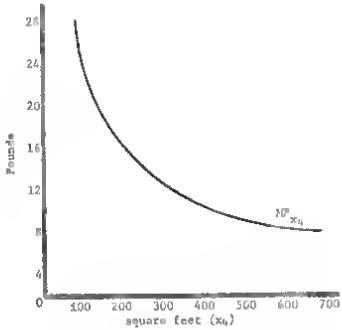


Figure 12 Marginal product curve for spiny lobster craft size ($MP_{x_4}$)

the production process, defined by diminishing marginal returns to the inputs. Number of traps ($x_1$) exhibited the largest returns to increased input usage, and had the highest statistical significance level of all explanatory variables. Estimates of rounds per week ($x_2$) revealed that marginal returns to more frequent pulls or longer set periods would be positive. Number of weeks fished ($x_3$) by law is limited to 36, although the analysis of weeks fished indicated that the economic feasibility of fishing beyond the 13th week is questionable. The diminishing marginal rate of returns to a firm was smaller for larger firms than smaller firms.

Optimum Resource Allocation of the Firm

The analysis and results of determining the level of inputs where profit was maximized for the typical firm are presented in this section.

This analysis was expanded to determine the optimum allocation of inputs for each size of craft classified by the sample stratification.

Optimum level of input usage is customarily determined by solving a system of equations determined from the first order conditions. In this case $x_1 - x_4$ can be considered as factors of production and $x_5$ and $x_6$ are simply area adjustment factors. Notationally, the equilibrium between value marginal product ($VMP_{x_i}$) and marginal factor price for each input ($x_i$) can be represented as

$$VMP_{x_i} = P_{x_i} \tag{42}$$

Thus the optimum solution for $x_1 - - - x_4$ is determined by simultaneously solving Equations 43-46

$$67.85\, x_1^{.2423} = P_{x_1} \tag{43}$$

$$5557.06\, x_2^{-.5601} = P_{x_2} \tag{44}$$

$$1180.39\, x_3^{-.6279} = P_{x_3} \tag{45}$$

$$602.67\, x_4^{-.6917} = P_{x_4} \tag{46}$$

The terms on the left of Equations 43-46 represent the value marginal products for the individual factors determined at the means of the other independent variables and at a product price of $1.00 per pound. Unfortunately the factor prices ($P_{x_i}$) were not unique exogenous prices. They were interdependent and thus presented problems in arriving at a unique solution. Factor price estimates of a trap ($P_{x_i}$) are possible and were the primary concern in this analysis. As mentioned earlier, the traps ($x_1$) variable was the principle factor through which all

inputs were translated into fishing effort. Although analyses of variables measuring effort intensity ($x_2$, $x_3$, and $x_4$) have provided useful production information, the principle reason for specification of these in the model was to allow for partial estimates of the trap effect. This model adjustment was required because the data base represented a cross-section of firms which varied with respect to $x_2$, $x_3$, and $x_4$. Thus an optimum solution in this analysis will be limited to (a) determination of optimal trap use for given (mean) levels of the adjustment variables and (b) discussion of possible or feasible levels of $x_2$, $x_3$, and $x_4$.

The price of an additional trap fished ($P_{x_1}$) is not simply the price of the trap but is the price of the trap and the cost of fishing the additional trap. This latter component presented difficulty in determining $P_{x_1}$. Total cost per firm was regressed on the number of traps fished per firm. OLS regression technique assuming BLUE estimate was used to estimate the total cost function (TC) expressed in Equation 47.

$$TC = \$1,876 + \$11.55\ x_1 \tag{47}$$

The coefficient of determination corrected for small sample size ($\bar{R}^2$) was .53 and the estimated coefficient ($11.55) for traps per firm was statistically significant at the 99 percent confidence level (t-value equal 5.328). The constant term ($1,876) was interpreted to represent fixed costs which do not vary with level of trap use. The coefficient, $11.55, represented the marginal factor price of an additional trap fished. Total costs were used for estimation rather than variable costs because a large component of trap cost was included in fixed cost

through depreciation.[1] The estimate of optimum number of traps per firm ($x_1$) using this factor cost estimate is presented in Table 9 with respective landings, profit levels, total revenue, and total cost.

Table 9. Optimum levels of trap usage per firm and resulting levels of profits, total revenue, total cost, and landings given trap cost, economic study of Florida spiny lobster industry

| Optimum level of trap use | Trap factor price ($P_{x_1}$) | Total revenue (TR) | Total costs (TC) | Profits ($\pi$) | Landings (q) (pounds) |
|---|---|---|---|---|---|
| $11.55 | 1,491 | $22,742 | $17,221 | $3,863 | 21,057 |

The optimum level of traps given a factor price of $11.55 was 1,491. Relatively small variations in the factor price of a trap produce significant changes in the estimated optimum level of traps. The highly variable nature of the optimum solution is significant in that it offered a possible explanation for the rapid increase in trap usage in the industry. Relatively small changes in producer price ($P_y$) or factor price of a trap ($P_{x_1}$) resulted in considerable expansion of fishing effort on trap usage. This finding justifies further consideration of trap usage in management considerations in the following chapter.

Before closing this chapter consideration of the remaining independent variables is warranted, given the earlier significant estimates of their marginal effects. One crude method for estimating the factor prices for $x_2$, $x_3$, and $x_4$ involves dividing total cost or total variable for each by the mean input levels of each of these factors. Estimates of

[1]Traps have an average life expectancy of three years.

total cost (TC), total revenue (TR), firm profit (Π), landings (q), and optimal levels $x_2$, $x_3$, and $x_4$, given the crude factor estimates of $P_{x_2}$, $P_{x_3}$ and $P_{x_4}$ are presented in Table 10. The remaining variables used in the estimation procedure are assumed constant at their sample mean.

Table 10 Optimum levels of adjustment factors ($x_2$, $x_3$, and $x_4$) and resulting levels of profits, total revenue, total cost, and landings per firm, economic study of Florida spiny lobster industry

| Optimum level of factor use ($x_i$)* | Factor price derivation | Estimated factor price ($P_{x_i}$) (dollars) | Total revenue (TR) (dollars) | Total costs (TC) (dollars) | Profits (Π) (dollars) | Landings (pounds) |
|---|---|---|---|---|---|---|
| .834 | $P_{x_2} = \frac{TVC}{x_2\ x_2}$ | 6,149.88 | 12,084 | 5,128 | 6,955 | 11,189 |
| 10.30 | $P_{x_3} = \frac{TC}{x_3\ x_3}$ | 273.00 | 7,559 | 2,812 | 4,747 | 6,989 |
| 179.11 | $P_{x_4} = \frac{TVC}{x_4\ x_4}$ | 17.70 | 9,690 | 2,991 | 718 | 8,972 |

Optimum number of rounds per week, or total percentage of traps pulled was .834.[1] The imputed factor cost for rounds per week was derived by dividing average total variable cost per firm from the sample by the mean level of rounds per week for the sample. Coincidentally, the optimum level of rounds per week ($x_2^*$) was equal to the mean of rounds per week from the sample ($x_2$) which resulted in a $6,955 profit for the typical firm. Imputed factor costs for weeks were derived by

[1]Length of set period, measured as days, is derived as follows: Days set period = $\frac{7}{x_2}$.

dividing total costs by the mean number of weeks in the sample. Optimum number of weeks was estimated at 10.3 and profit per firm was estimated at $4,747. Optimum size of craft measured as square footage of hull was estimated at 179.11 square feet. Factor costs were derived by dividing total variable costs by mean craft size for the sample. At this level of craft size profit estimated for the typical firm was $718.

This procedure was presented for illustrative purposes and its usefulness depends on accurate estimates of factor prices. In addition, total revenue, total cost, and resulting profits were also dependent on levels of other inputs which in the above analysis were held at mean levels rather than "optimal" levels. However, it is interesting to note that the predicted level for rounds per week and weeks fished in Table 10 were both close to actual observed values in the industry, thus suggesting that if firms are maximizing profits, the above estimates of factor prices for $x_2$ and $x_3$ are reasonable. The factor price estimated for craft size evidently may be a substantial error because the optimal hull size of the typical craft was predicted at 179.11 square feet, considerably different from the current industry average size of 326.88 square feet. Furthermore, the predicted profit per firm of $718 does not appear reasonable given the survey data.

At this point, one additional conclusion was indicated with respect to variations in firm profits due to fishing areas. Fishing in the upper ($x_5$) and lower ($x_6$) Keys regions produced increased profits. However, only $\hat{\beta}_5$ was statistically significant at the 99 percent confidence level, compared with a 56 percent confidence level for $\hat{\beta}_5$. Therefore, there exists a good chance profits will be greater if firms fish above Lower Matecumbe Key rather than fish the adjacent area down to Big Pine

Key. Fishing in the region below Big Pine to Key West most probably does not increase a firm's profits compared to fishing the area from Big Pine Key up to Lower Matecumbe Key. The model would have to be respecified to determine if there exist only two significantly different fishing grounds (regions), i.e., above and below Lower Matecumbe Key. Empirical values for the fishing effort and price variables were held at the respective 1973 levels: 618, for $x_1$, .834, for $x_2$; 33.08, for $x_3$, and 326.88, for $x_4$. Product price, $P_y$, was assumed equal to $1.08 per pound.

## CHAPTER VI

## THE MANAGEMENT MODEL

The purpose of this chapter is to present a framework with which decisionmakers can evaluate management policies. The framework is based on results from the estimated time-series bioeconomic industry and firm harvest models in the study. In the first section the analysis of maximum economic yield (MEY) for the industry is presented. Next, analyses of alternative combinations of traps per firm and number of firms are presented. Finally, the alternative management considerations outlined in the study objectives are analyzed.

### Maximum Economic Yield for the Industry[1]

When the quantity of lobster harvested is such that the cost of an additional unit of input ($P_{X_i}$) is equal to the value of the marginal product ($VMP_{X_i}$) for that input, then maximum economic yield with respect to the given input ($MEY_{X_i}$) is achieved. Maximum economic yield with respect to inputs $X_1$ and $X_2$ can be determined by first simultaneously determining the optimal level of both inputs. These input levels are then substituted into the production function (Equation 22) to predict MEY. To determine optimum levels of $X_1$ and $X_2$ for the industry simultaneously, the profit function (Equation 47) is differentiated with

[1]Recall that capital notations for the variables represent industry inputs and lower case type for variable notations represent firm inputs. $P_y$ represents ex-vessel product price in the firm and industry models.

respect to $X_1$ and $X_2$ and set equal to zero to determine a maximum (or minimum) level of inputs.

$$\Pi = TR - TC$$

$$\Pi = P_y \left(K + \frac{\hat{\theta}_1}{X_1} + \frac{\hat{\theta}_2}{X_2}\right) - X_2[1876 + 11.55\ X_1] \qquad (48)$$

where,

$\Pi$ = industry profit,

$1876 + 11.55\ X_1$ = per firm total costs expressed as a function of traps, and other terms are defined as before.

$$\frac{\partial \Pi}{\partial X_1} = -\frac{\hat{\theta}_1 P_y}{X_1^{\ 2}} - 11.55\ X_2 = 0 \qquad (49)$$

$$\frac{\partial \Pi}{\partial X_2} = -\frac{\hat{\theta}_2 P_y}{X_2^{\ 2}} - 1876 - 11.55\ X_1 = 0 \qquad (50)$$

Solving Equations 48 and 49 simultaneously results in 213 firms in the industry, each fishing 795 traps. Using Equation 22 maximum economic yield was estimated at 5,778,274 pounds. This estimate was 16 percent higher than industry landings in 1973. The number of firms in the industry, at 399 in 1973, was 87 percent higher but each firm fished 429 traps, 87 percent less than the estimated value. Several implications can be drawn from this analysis. First, industry profits have currently not been maximized nor has total industry landings reached a peak. Second, firms could be larger and more efficient, maximizing profits through economies of size. Finally, total industry costs could be reduced due to fewer firms, resulting in a larger total industry profit.

Maximum economic yield was less than the estimated maximum sustainable yield (MSY) and resulted from an optimum allocation of factor

resources. However, management authorities allocating factor resources could consider factors such as "grandfather clause" and minimum levels of input use (such as more firms than the optimum 213 firms solved for in this study). Consequently, only one input at a time will most likely be considered for regulation. Alternatively, the management authorities may not strive to reach the most profitable level of utilization, at least initially, since social and political institutions must be considered. For these reasons the remainder of this chapter will consider alternative levels of maximum economic yield with respect to given constraints. That is one input will be analysed while other inputs are held at current levels.

Evaluating MEY

Maximum economic yield was estimated in the previous section using the bioeconomic industry harvest model. In the previous chapter it was explained that the traps data used to estimate the parameters for the industry model were not adjusted for influences that make a trap catch "better" for one firm than another. The reason for this was that data such as that used to estimate the parameters for the firm harvest model were not available over time. Trap data in the analysis of the firm harvest function included these influences making estimation of the optimal number of traps a partial effect and probably more accurate. Consequently, MEY was reestimated constraining the number of traps per firm to three levels most likely to be politically acceptable based on analysis in this study. This evaluation involves comparing landings (MEY), total revenues (TR), total costs (TC), and profits (Π) for the industry and the firm, among the three levels of traps per firm ($X_1$).

The technique used to reestimate MEY was different than the first method which involved a simultaneous solution of the industry profit function. In this case the assumed number of traps per firm ($X_1$) and the estimated optimal number of firms ($X_2^*$) required for industry profit maximization was substituted into the original bioeconomic industry harvest function. In the following equation landings are now defined as maximum economic yield (MEY) for a given combination of traps per firm ($X_1$) and number of firms ($X_2$), assuming a constant mean seasonal water temperature ($X_3$) of 77.591°F.

$$MEY = \hat{a} + \frac{\hat{\beta}_1}{X_1} + \frac{\hat{\beta}_2}{X_2^*} + \hat{\beta}_3(77.591). \qquad (51)$$

The optimal number of firms ($X_2^*$) was defined as that number which maximized industry profit while fishing the number of traps per firm that was specified for the estimation of MEY. Consequently, total cost per firm and resulting total industry cost varies according to the number of traps specified.[1] Optimal number of firms was derived for each level of traps per firm from the following equality between the value

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[1] $P_{X_2}$ was previously defined as average total cost per firm for the industry. Alternatively, the estimated value of $P_{X_2}$ can be considered to be a function of the number of traps the firm fishes. The estimation of $P_{X_2}$ using OLS regression technique was

$$P_{X_2} = 1,876 + 11.55\ X_1$$

where,

$SE_{X_1} = 2.168$, $SE_a = 1,540$, $R^2 = .74$, SEE = 3,752, d.f. = 23 and

$P_{X_1} = \$11.55$.

of the marginal product for number of firms ($VMP_{X_2}$) and the total cost per firm ($F_{X_2}$).

$$VMP_{X_2} = F_{X_2}$$

$$X_2^* = \left[\frac{\hat{b}_2 P_y}{F_{X_2}}\right]^{\frac{1}{2}} \tag{52}$$

where,

$VMP_{X_2} = MP_{X_2} \cdot P_y$, the marginal product of firms multiplied times the ex-vessel price per pound ($P_y$),

$F_{X_2} = 1,876 + 11.55\ X_1$, the firm total cost function, and

$X_2^*$ = optimal number of firms estimated.

The three levels of traps per firm ($X_1$) selected to reestimate MEY were (a) the 1973 mean number of traps per firm for the industry (429), (b) the mean number of traps per firm in the survey (618), and (c) the optimal number of traps per firm for profit maximization estimated in the firm analysis from cross-sectional data. The respective optimal number of firms ($X_1^*$) estimated from Equation 51 are (a) 271 firms fishing 429 traps each, (b) 236 firms fishing 618 traps each, and (c) 225 firms fishing 700 traps each. The criteria for evaluation are presented in Table 11. Comparable values can be derived for the typical firm by dividing the table values by the appropriate number of firms.

In Table 11, landings were estimated at 4.7 million pounds given the optimum number of firms (271) estimated from Equation 51. Each of these firms were assumed fishing 429 traps. If all firms fished 618 traps instead (the cross-sectional sample mean), 236 firms would be the optimum number required for a maximum industry profit which would be $3.8 million.

Table 11 Maximum number of firms ($X_2$*), landings, revenues, and costs for industry profit maximization given desired management levels of traps per firm ($X_1$), economic study of Florida spiny lobster industry

| Optimum number firms ($X_2$*) | Traps per firm ($X_1$) | Landings (MEY) | Total revenue (TR) | Total cost (TC) | Profit (Π) |
|---|---|---|---|---|---|
| 271 | 429 | 4,700,384 | 5,076,414 | 1,851,201 | 3,225,213 |
| 236 | 618 | 5,472,346 | 5,910,134 | 2,127,304 | 3,782,830 |
| 225 | 700 | 5,648,932 | 6,100,846 | 2,241,225 | 3,859,621 |

Notes: Definitions for Table 11

$X_2$* = Determined as optimum level of $X_2$ given $X_1$ for profit maximization ($VMP_{X_2} = P_{X_2}$).

$X_1$ = Assumed desired management levels for $X_1$ as previously defined.

MEY = Maximum economic yield given $X_2$* and $X_1$

TR = Total revenue from landings, assuming 1974 ex-vessel price ($P_y$) of $1.08 per pound (TR = $P_y$ · MEY).

TC = Total operating costs [TC = $X_2$(1,876 + 11.55 $X_1$)].

Π = Profit; total revenue (TR) minus total cost (TC)

This would result in total landings of approximately 5.5 millium pounds. As number of traps fished per firm increases to 700, the optimum number of firms required for profit maximization is 225, resulting in landings of 5.6 million pounds. Thus for given levels of traps per firm which have either been observed or estimated as typical in this study, the optimum number of firms required in the industry to maximize industry profits ranges from 225 to 271 firms. Maximum economic yield for these input levels was also within a reasonable estimate ranging from 6 percent below 1973 landings of 5 million pounds to 12 percent above

Estimated earnings and costs for the input levels are also presented in Table 11. These estimates are with respect to 1973-74 season stock levels and environmental conditions

Policy Implications

The estimated MSY of six to seven million pounds presented in Chapter IV currently has not been attained. Landings are within 20 to 40 percent of this estimate of MSY. It appears unlikely, given the estimated MEY of 5.8 million pounds, that fishing effort will cause landings to surpass MSY, at least in the near future. This is based on the fact that 7 million pounds are not reached until 649 firms enter the industry with 700 traps each. With the 400 firms presently in the industry each would have to fish 1,000 traps to harvest 7.2 million pounds. These levels of inputs are considerably above typical levels found in the industry. Therefore, the current major concern facing the regulatory agency is maintaining a politically acceptable maximum economic yield (MEY) for the industry.

From the evaluation of MEY it is obvious the policy maker is faced with numerous choices of combinations of traps per firm and number of firms. The optimum combination of these resources depends on the state's management objectives. For example, objectives based upon a strict profit maximization motive may lead to regulatory legislation that would reduce the current number of firms to less than 300 (based on Table 11), allowing only the most efficient firms to operate. Conversely, objectives based on a social welfare optimization motive may very well encourage maximum entry of less efficient firms. The number of firms would be limited only by the probability of landings surpassing MSY.

As more biological information concerning MSY becomes available, the relationship between MSY and MEY will become more useful in developing management guidelines. An analysis of the impacts of a wider range of various combinations of inputs and management objectives is presented in the next section.

## Discrete Analysis of Alternative Combinations of Firms and Traps Per Firm

Extreme variation may occur in the impact of the different management programs, depending on which resource ($X_1$ or $X_2$) is manipulated and to what degree. Thus it is extremely important to know the impact of various combinations of these resources in order to design policy goals and select parameters for management programs. To illustrate this point Tables 12 and 13 were developed to show the impact of various combinations of traps per firm and numbers of firms, measured as landings (Q, q), total revenue (TR), total cost (TC), and profit (Π) for the industry and the average firm. Table 12 was developed for various numbers of firms in the industry holding traps per firm at 700 traps. Illustrated in Table 13 are various levels of traps per firm holding number of firms at the 1973-74 season level of 400 firms.

### Alternative Number of Firms in the Industry

Seven hundred traps per firm were assumed because this figure was felt to be a realistic estimate given results of the various analyses. In the previous chapter, the average number of traps per firm in the cross-sectional firm analysis was found to be 842 for the size group with the highest profits. The average number of traps for the group with the second highest profit level was 561. For these two groups combined

there was an average of 701 traps per firm. Finally, the MEY analysis using the bioeconomic industry harvest function at the beginning of this chapter resulted in 795 traps per firm as optimum.

Industry landings (Q) ranged from 3.1 to 7.4 million pounds as the number of firms has varied from 100 to 1,500 in Table 12. This range represents only a 141.7 percent increase in total industry landings as the result of a 1,400 percent increase in effort. Total costs become greater than total revenues when the number of firms exceeds 966. If the 1973-74 season level of 400 firms were in effect, landings would be 6.6 million pounds with industry profits of $3.1 million. Thus, if each firm fished 700 traps (selected economic optimum for 1974) 225 firms would maximize industry profits. Approximately 772 firms would likely dissipate all industry profits, while the 400 existing firms could operate at a total industry profit level of $3.1 million. Maximum industry profits would occur with 225 firms, each fishing 700 traps. This would result in landings of 5.6 million pounds.

Estimates on a per firm basis presented in Table 12 were derived by dividing total industry estimates by the appropriate number of firms. Estimated landings per firm (q) ranged from 4,938 to 30,646 pounds for the alternative programs. Costs per firm were constant in Table 12. Estimated average profits per firm ranged from $23,137 for 100 firms in the industry to $3.00 per firm for 771 firms in the industry. Total costs per firm were estimated to exceed total revenues per firm when the number of firms exceeded 771. With these estimates maximum profit per firm occurred at 121 firms while maximum industry profit occurred at 225 firms.

Table 12 Analysis of alternative levels for number of firms ($X_2$) assuming traps per firm ($X_1$) equals 700, mean seasonal water temperature ($X_3$) equals 11.591°F, and ex-vessel price per pound ($P_y$) equals $1.02. economic study of Florida spiny lobster industry

| | Total Industry | | | | Per Firm | | | |
|---|---|---|---|---|---|---|---|---|
| Number of firms ($X_2$) | Landings (Q) | Total Revenue (TR) | Total Cost (TC) | Profit (T) | Landings ($q_i$) | Total Revenue (TR) | Total Cost (TC) | Profit (T) |
| 100 | 3,984,612 | 3,101,893 | 996,190 | 1,111,703 | 39,841 | 31,018 | 9,961 | 11,111 |
| * 121 | 3,811,919 | 4,181,716 | 1,265,201 | 1,916,431 | 31,500 | 34,560 | 10,461 | 14,599* |
| 110 | 4,611,312 | 4,984,121 | 1,414,110 | 1,410,119 | 41,921 | 45,310 | 12,851 | 12,819 |
| 115 | 5,018,111 | 5,462,091 | 1,141,115 | 1,119,119 | 43,636 | 47,514 | 12,561 | 21,251 |
| 100 | 1,110,101 | 1,011,741 | 1,191,200 | 3,819,141 | 11,911 | 19,101 | 11,961 | 19,148 |
| * 221 | 1,148,912 | 6,100,846 | 2,141,121 | 3,851,111* | 25,101 | 21,114 | 9,461 | 17,153 |
| 211 | 1,741,216 | 6,204,918 | 2,110,168 | 1,814,193 | 18,144 | 16,292 | 9,961 | 16,331 |
| 2 1 | 5,191,851 | 6,419,852 | 2,699,411 | 1,180,411 | 11,140 | 11,911 | 1,561 | 11,950 |
| 300 | 6,111,112 | 1,619,011 | 2,180,300 | 3,110,715 | 20,311 | 17,197 | 1,561 | 17,116 |
| 315 | 8,285,061 | 1,787,073 | 3,211,121 | 3,550,140 | 11,219 | 20,858 | 9,961 | 20,121 |
| 310 | 1,381,101 | 6,898,208 | 3,606,150 | 1,411,130 | 18,149 | 18,209 | 9,911 | 9,140 |
| 115 | 8,415,808 | 6,191,911 | 1,115,1 1 | 3,210,001 | 11,161 | 18,611 | 9,961 | 2,690 |
| 400 | 6,151,411 | 2,017,112 | 3,006,100 | 1,091,112 | 14,161 | 13,695 | 9,961 | 1,114 |
| 425 | 6,621,245 | 7,111,591 | 4,131,415 | 2,118,161 | 11,181 | 13,611 | 1,161 | 6,861 |
| 450 | 6,682,612 | 7,217,164 | 1,611,410 | 2,136,014 | 14,850 | 13,038 | 9,161 | 6,971 |
| 100 | 6,185,014 | 1,320,006 | 1,100,500 | 2,340,401 | 13,571 | 14,158 | 8,911 | 4,697 |
| * 11. | 1,113,031 | 7,682,016 | 7,619,131 | 2,145* | 8,226 | 9,914 | 9,981 | 3* |
| 1000 | 1,211,198 | 7,031,294 | 1,911,000 | -1,120,706 | 7,211 | 7,031 | 1,961 | -2,130 |
| 1500 | 1,404,216 | 7,198,158 | 14,941,500 | -6,141,714 | 4,918 | 5,133 | 9,161 | -4,628 |

Notes: Asterisks highlight minimum and maximum positive profits for firms and/or industry and respective number of firms ($X_2$)

Alternative Levels of Traps Per Firm

The effects of varying traps per firm from 200 to 1,000, holding the number of firms at the 1973-74 level of 400, is presented in Table 13. Total industry landings (Q) decreased from a maximum of 7.2 million pounds using 1,000 traps per firm to 1.4 million pounds using 200 traps per firm. At levels less than 205 traps per firm total costs were greater than total revenues (Table 13). Maximum profit for the industry and per firm occurred when the average number of traps per firm was 580. At this level total industry landings were 6.1 million pounds.

Landings (q) per firm ranged from 3,527 to 17,926 pounds for a variation in traps from 200 to 1,000 traps per firm. Total costs per firm ranged from $4,186 to $13,426 at these input levels. Profits per firm ranged from a maximum $7,970 with 580 traps per firm to $39 with 205 traps per firm. At 618 traps per firm (sample mean) total industry landings (Q) were 6.3 million pounds. This level of landings was greater than the 5.3 million pounds estimated using the mean number of traps per firm in the time-series analysis (429 traps per firm).

Evaluation of Estimates

Model estimates thus far appear to be reasonable in comparison to actual primary and secondary data. In 1973, 399 firms fishing an average of 429 traps entered the industry and landed 4.99 million pounds. According to the analysis, 400 firms each fishing 429 traps would land approximately 5.3 million pounds. The average full-time firm earned a profit of $8,710 in 1973 fishing 618 traps (Prochaska and Williams [37]). This compares with the estimated profit of $7,943 per

Table 13 Analysis of alternative levels for number of traps per firm ($X_1$) assuming number of firms ($X_2$) equals 600, mean seasonal water temperature ($X_3$) equals 55 591°F and ex-vessel price per pound ($P_y$) equals $1.00 economic study of Florida spiny lobster industry

| | Total Industry | | | | Per Firm | | | |
|---|---|---|---|---|---|---|---|---|
| Traps per Firm ($X_1$) | Landings (Q) | Total Revenue (TR) | Total Cost (TC) | Profit (Q) | Landings (q) | Total Revenue (TR) | Total Cost (TC) | Profit (Q) |
| 1000 | 7 150 570 | 5,544,515 | 5 570 400 | 5,553,013 | 12 958 | 10 361 | 13 456 | 5 935 |
| 800 | 6 810,556 | 7 353,425 | 4 446 600 | 2,505 052 | 15 016 | 10 389 | 11,116 | 7,553 |
| 500 | 6,535,655 | 7,055,512 | 3 984 400 | 3 093 312 | 16,384 | 15 696 | 5,561 | 7 733 |
| 600 | 6 580 600 | 6 505,956 | 5 005,560 | 3,155 566 | 15 501 | 16 555 | 5,014 | 7 943 |
| 560 | 6 157 878 | 6 618,054 | 3 430,000 | 3,180 054* | 15 320 | 16,545 | 8,583 | 7,958* |
| 500 | 3 730,553 | 8 165,841 | 3 080,400 | 3 158,641 | 14,556 | 13,453 | 5,651 | 7 652 |
| 429 | 3,255 950 | 5,674,253 | 2,535,500 | 2,941 093 | 13 115 | 14 186 | 6,831 | 7 353 |
| 400 | 3,010 605 | 5,411,656 | 5,598,400 | 2 615 054 | 15 515 | 13,525 | 6,456 | 7,033 |
| 300 | 3,810 625 | 4 115,455 | 2,136 400 | 1,959 053 | 5,527 | 10,269 | 3,341 | 4,948 |
| 285 | 1 588 572 | 1,513,153 | 1 695,500 | 15 653* | 3 986 | 4,005 | 4,264 | 39* |
| 200 | 1,410 865 | 1,523 518 | 1,654 400 | -158 882 | 3,355 | 3,809 | 4 196 | -357 |

Note: Asterisks highlight minimum and minimum positive profits for firms and/or industry and respective level of traps per firm ($X_1$)

firm using 61% traps.[1] These estimates are not unrealistic when one considers that the number of firms in the secondary data includes small part-time and recreational firms with low net revenues as well as large commercial firms.

Discrete input substitution analysis was limited by the fact that only a limited number of selected combinations of input levels can be evaluated. However, it was possible to evaluate all economically feasible combinations of number of traps per firm and number of firms in the industry by analyzing isoquants developed from the bioeconomic industry harvest model.

## Isoquant Analysis

A production isoquant can be defined to show the various combinations of traps per firm ($X_1$) and number of firms ($X_2$) that are capable of harvesting a given level of landings (Q). The isoquant can then be used by analyzing the marginal rate of technical substitution between inputs to illustrate the broad range of alternative combinations of traps per firm and firms to achieve management objectives and the ultimate limit of the use of a particular resource.[2]

The rate at which traps per firm ($X_1$) and number of firms ($X_2$) are substituted for each other is important in determining the results of changes in the combination of inputs. This rate can be defined as the

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[1] Total costs do not include opportunity costs such as captain's salary and returns to investment. Captain's salary was estimated at $5,130 for the typical firm.

[2] Notationally isoquants in Figure 13 can be represented as

$$X_1 = \hat{\beta}_1 \left[ Q - \hat{a} - \frac{\hat{\beta}_2}{X_2} - \frac{\hat{\beta}_3}{X_3} \right]$$

marginal rate of technical substitution of traps per firm for firms ($MRTS_{X_1X_2}$) and is expressed in the following equation.

$$MRTS_{X_1X_2} = -\frac{dX_1}{dX_2} = -\frac{MP_{X_1}}{MP_{X_2}} . \qquad (\text{[illegible]})$$

$MRTS_{X_1X_2}$ is the reduction in number of traps per firm necessary to maintain the same level of landings after an increase in the number of firms.

Using input levels for the 1973-74 season as set forth in the time-series data, $MRTS_{X_1X_2}$ was estimated to be[1]

$$MRTS_{X_1X_2} = -\left(\frac{\hat{B}_1}{X_1}\right)\left(\frac{\hat{B}_2}{X_2}\right)^{-1} = -2.69 . \qquad (54)$$

Increasing the number of firms in the industry ($X_2$) from 400 to 401 would require decreasing the number of traps per firm ($X_1$) by three (2.69 rounded)[2] to 426 traps to maintain 1973 landings of 5,253,958 pounds. This would result in a total decrease of only 774 traps in the industry.[3] Total cost per firm would decrease by $34.65. Constant landings would result in an identical level of industry total revenue, but the additional firm in the industry would decrease average revenue per firm by $91.23. The reduction of 826 traps would reduce industry total costs by $7,064 and thus increase industry total profit.

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[1] Assuming 429 $X_1$, 400 $X_2$, $1.08 $P_y$, TC equal to $1876 + $11.55 $X_2$

[2] $MRTS_{X_1X_2}$ = 2.69 is rounded to 3.0 since inputs are indivisible thus not accurately maintaining the equality of MSY and total revenues.

[3] (400 x 429) - (401 x 426) = 774.

$MRTS_{X_1X_2}$ diminishes as more firms are substituted for traps per firm and this is illustrated by the concave isoquants in Figure 13. This condition is recognized as satisfying the principle of diminishing marginal rate of technical substitution and is caused by two factors. First, the marginal product of firms ($MP_{X_2}$) diminishes as the number of firms increases while the number of traps per firm is held constant. This is defined as a downward movement along the $MP_{X_2}$ curve. Second, as the number of traps per firm decreases, the marginal product function of firms decreases (thus shifting the $MP_{X_2}$ curve downward). As more firms ($X_2$) are substituted for fewer traps per firm ($X_1$) the marginal productivity of the additional firm in the industry will be less. The opposite occurs as the number of traps per firm ($X_1$) is substituted for the number of firms ($X_2$). The same two forces act to increase the marginal product of number of traps per firm ($X_1$) while the marginal product function of number of firms ($X_2$) decreases.

Analysis of the marginal rate of technical substitution between inputs can be of importance in providing a priori information to decision-makers about the results of suggested changes in the structure of the harvesting sector of the fishery. This analysis includes (a) observing the effect of movements along an isoquant and (b) determining the location of ridge-lines (defined).

Movement Along An Isoquant

For firms fishing 700 traps, $MRTS_{X_1X_2}$ ranges from -.0632 for 100 firms to -14.2143 for 1,500 (Table 14). $MRTS_{X_1X_2}$ for 249 firms (-.3922), for example, means that if decision-makers decided to allow the number of firms in the fishery to increase by one to 250, and yet still maintain

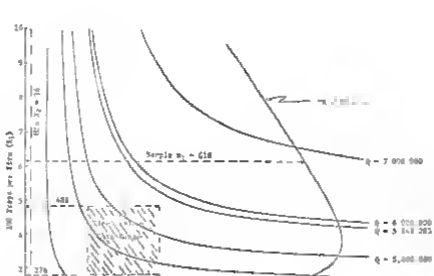


Figure 13. Spiny lobster harvest isoquants and ridge lines defining expansion paths where returns equal total costs, (assuming ex-vessel price per pound ($P_y$) equals $1.08, industry total cost equals $1,875 plus $11.55 per trap per firm ($X_1$), and mean seasonal water temperature ($X_3$) equals 77.591°F)

the previous level of landings (5,848,203 pounds) where industry profits were maximized, the number of traps per firm would have to be decreased by 2.55.[1] This was illustrated in Figure 13 as moving along the isoquant where landings (Q) equals 5,848,203 pounds.

Table 14. Marginal rate of technical substitution ($MRTS_{X_1X_2}$) of traps per firm ($X_1$) for number of firms ($X_2$) holding traps per firm constant at 700, economic study of Florida spiny lobster industry

| Number of firms ($X_2$) | Marginal rate of technical substitution ($MRTS_{X_1X_2}$) |
|---|---|
| 100 | - .0632 |
| 150 | - .1421 |
| 200 | - .2527 |
| 250 | - .3922 |
| 300 | - .5686 |
| 350 | - .7739 |
| 400 | - 1.0108 |
| 425 | - 1.1411 |
| 450 | - 1.2793 |
| 500 | - 1.5794 |
| 1000 | - 6.3175 |
| 1500 | -14.2143 |

Carrying this example one step further and assuming a $1.08 product price and previously estimated total costs per firm, the net effect on industry and firm profits can be easily approximated. Since each firm is fishing approximately three (2.55 rounded) fewer traps with the additional firm in the fishery, total costs per firm decreased by $11.55

[1] Notationally this can be expressed as

$$\frac{1}{MRTS_{X_1X_2}} = -\Delta X_1.$$

For $X_1 = 700$ and $X_2 = 250$, the change in $X_1$ was $-\frac{1}{.3922} = -2.55$

times 2.55, or approximately $35.00, but industry total costs increased by $12.99. This amount is due to increased fixed costs generated by the additional firm. Furthermore, industry total revenue remains unchanged since product price was held constant and landings were unchanged due to substitution of inputs along the isoquant. However, total revenues per firm decrease by approximately $101 because the same level of total industry revenues was divided by one additional firm.

The analysis of the marginal rate of technical substitution between inputs can also provide useful information in deciding which inputs should be changed (limited or allowed to increase) to induce desired changes in sustainable yield levels. For example, at 400 firms in the fishery, $MRTS_{X_1X_2}$ equals approximately unity (1.0108) and substituting either traps per firm ($X_1$) or number of firms ($X_2$) for the other at this point would not significantly change total industry landings. As more than 400 firms enter the industry, the marginal increase in industry landings is greater if increments are made in traps per firm than if additional firms are allowed in the industry. At 425 firms the marginal product of traps per firm ($MP_{X_1}$) is 14.1 percent greater than the marginal product of number of firms ($MP_{X_2}$), and at 500 firms, $MP_{X_1}$ is 57.9 percent greater than $MP_{X_2}$. This suggests that once the number of firms exceeds approximately 425, further efficiency in industry harvesting costs is questionable. This is assuming, of course, that proportionate increases in costs per trap are not unreasonably higher than costs per firm, which is highly unlikely. Therefore, if some reasonable level of profit maximization is part of the overall management goal, no more than 425 firms should be allowed to enter the industry, based on the assumptions of this analysis.

Ridgelines

The boundary lines shown in Figure 13 indicate the maximum amount of one input that can be combined with another input without causing profits to be negative. This boundary is calculated at those points where the firm's total revenue equals total cost.[1] The boundary lines were calculated by setting total revenue minus total operating cost equal to zero and then solving for each input in terms of the other. The economically feasible combinations of traps per firm ($X_1$) and number of firms ($X_2$) are shown in Figure 13. The area between the ridge lines defines the region of profits for the firm. Note that any number of firms beyond approximately 950 will result in negative returns at any level of trap use. The minimum number of firms required to yield revenues equal to costs was 16. The left-hand ridge-line asymptotically approached this limit of firms ($X_2$), but beyond the realistic range of traps per firm ($X_1$). The production function specified that a minimum of 51 traps per firm was required to lead a positive yield, but when costs of production are considered, at least 207 traps per firm were

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[1]The right-hand ridge-line is expressed as the following relationship:

$$P_y(K - \frac{\hat{\beta}_1}{X_1}) = \frac{\hat{\beta}_2}{X_2} P_y + TC\ X_2$$

The left-hand ridge-line can be expressed as

$$P_y K - P_y \frac{\hat{\beta}_2}{X_2} - 1,876\ X_2 = P_y \frac{\hat{\beta}_1}{X_1} - 11.55\ X_1 X_2$$

where,

$k = \hat{\alpha} - \hat{\beta}_3 X_3 = 977348 0.707$,

$X_3 = 77.591$,

TC = total operating costs (previously defined), and

$P_y$ = \$1.08 per pound.

required, as indicated by the zero slope of the lower left-hand ridge-line. The feasible range for traps per firm increased above 250 traps as revenues remained above costs.

Summary of Management Tools

When combined with reliable input cost information, isoquant analysis can be a very effective tool in evaluating the impact of management strategies. Discrete analysis is useful if one of the input levels has been pre-determined, which may often be the case due to social and institutional constraints. An unconstrained maximum economic yield can be determined by solving the first order conditions of the industry profit function. If inputs are limited, maximum economic yield can be derived by substituting the particular input constraint and an estimate of the optimal profit maximizing level of the other input into the bioeconomic industry harvest model.

These tools have been developed as a result of this study to aid in the design and evaluation of management strategies. With this goal in mind the remainder of this chapter is devoted to analyzing a few selected traditional management programs and a suggested management strategy designed from the tools presented in this study.

Analysis of Traditional Management Programs

Types of traditional management programs considered in this study were (a) regulating inputs through licensing and (b) issuing landings quotas. Specific evaluation criteria included were industry revenues, harvesting costs, and enforcement costs. Revenues to the state to cover implementation and enforcement costs were analyzed with respect to revenues available from license fees and/or taxes on landings.

For each of the programs analyzed the following assumptions were made, unless otherwise specified: ex-vessel price per pound ($P_y$) equaled $1.08 (1974 mean price); number of firms in the industry ($X_2$) was 400 (1973 level), traps per firm ($X_1$) was 618 (sample survey mean), desired level of landings (Q) equaled 5 million pounds (1973 level); and total cost per firm equaled $1876 plus $11.55 per trap (estimated).

Licensing Traps

Licensing of traps and the charging of a fee increases costs but appears economically and politically feasible, provided that some form of "grandfather clause" is included which limits the number of firms in the industry to at least those that were previously fishing.[1] As the cost of traps increases, the number of traps per firm must be reduced to obtain higher marginal productivities so that the value of the marginal product can equal the higher trap cost. This would reduce effort in the form of traps as captains attempt to maximize profits.

As a way of illustrating the effects of this program, consider the analysis in Table 15. Total landings would be 6.28 million pounds and average firm profits would be $7,325, if 618 traps were employed per firm. Given assumed desired annual landings of 5 million pounds, a reduction in average traps to 400 per firm would be required. Industry profit would be $2.65 million after the reduction, a portion of which may be taxed through a license to finance the management of the program. After deducting opportunity costs in the form of captain's wages and

[1]A "grandfather clause" refers to legislation which states that fishermen licensed prior to the enactment of some limited entry regulation must be allowed to remain in the fishery.

Table 15 Analysis of alternative levels for number of traps per firm ($X_1$) assuming number of firms ($X_2$) equals 400, mean seasonal water temperature ($X_3$) equals 77.191°F., ex-vessel price per pound ($P_y$) equals $1.00, and trap licence fee equals $1.00 per trap, economic study of Florida spiny lobster industry

| | Total Industry | | | | Per Firm | | | |
|---|---|---|---|---|---|---|---|---|
| Number of Firms ($X_2$) | Landings (Q) | Total Revenue (TR) | Total Cost (TC) | Profit (Z) | Landings (q) | Total Revenue (TR) | Total Cost (TC) | Profit (Z) |
| 1000 | 7,170,570 | 7,744,115 | 1,770,440 | 1,971,615 | 17,916 | 19,561 | 14,426 | 4,911 |
| 800 | 6,810,576 | 7,151,412 | 4,766,400 | 2,509,022 | 17,616 | 18,169 | 11,116 | 6,471 |
| 700 | 6,111,417 | 7,077,711 | 4,264,400 | 2,815,111 | 16,184 | 17,694 | 10,661 | 7,015 |
| 615 | 6,280,487 | 6,701,126 | 1,812,760 | 1,930,166 | 15,701 | 16,957 | 9,652 | 7,511 |
| * 517 | 6,011,310 | 6,507,515 | 3,146,540 | 2,160,795* | 11,063 | 16,168 | 6,064 | 7,402* |
| 100 | 5,730,595 | 6,161,041 | 5,260,400 | 2,928,641 | 14,126 | 11,471 | 8,111 | 7,112 |
| 429 | 5,111,916 | 1,674,171 | 1,903,920 | 3,703,291 | 15,151 | 14,186 | 7,280 | 6,126 |
| 400 | 5,010,601 | 5,411,454 | 1,758,400 | 2,653,054 | 12,127 | 11,121 | 6,106 | 6,631 |
| 300 | 5,010,626 | 4,111,475 | 2,156,400 | 1,619,071 | 1,127 | 10,289 | 5,641 | 4,648 |
| * 207 | 1,654,131 | 1,766,470 | 1,709,546 | -5,070* | 4,111 | 4,466 | 4,474 | -8* |

Note Asterisks highlight minimum and maximum positive profits for industry and/or firms and respective level of traps per firm ($X_1$)

returns on investment from each firm's profit, the residual could be considered the maximum amount in total fees the firm could afford to pay. This value divided by the number of traps is the maximum trap fee.

If management objectives would insure the maintenance of a minimum $5,000 salary for the captain and average profit of $7,325 for the firm, the maximum trap license fee would be $5.81[1] per trap. Any difference between a lower fee and $5.81 would be considered residual returns to ownership. To compute the values in Table 15, the trap fee was treated as an additional variable cost to the firm and added to the estimated $11.55 cost per trap.

The optimum number of traps per firm which resulted in maximum profits per firm ($7,970) was 580 (Table 13) when no license fee was imposed. Optimum number of traps decreases to 557 if a $1.00 per trap license fee[2] is charged. This results in maximum profits per firm decreasing to $7,402 (Table 15). The number of traps per firm required to maintain industry landings at the assumed desirable management level of 5 million pounds would not change, but profit per firm at this level would drop 5.7 percent to $6,623 due to the trap license fee. Profit per firm ranged from near zero to $7,402 with the license fee (Table 15), compared with near zero to $7,970 without the license fee (Table 13). The percentage difference in firm profits ranged from 6 to 17 percent and was greatest at the higher levels of traps per firm ($X_1$). Beyond 207 traps per firm, the firm does not return a profit if a $1.00 license must be paid. This source compared with 205 traps per firm without a

[1] ($7,325 - $5,000) ÷ 400 traps = $5.81 maximum license fee.

[2] Considered in the range of a politically feasible fee.

license fee. Notice that beyond 400 traps per firm no regulation of traps is needed to maintain the desired harvest of 5 million pounds if the number of firms is limited to 400.

As estimates of enforcement and implementation costs increase the license fee would need to be adjusted accordingly. The estimates presented in this section would change as different management objectives and values are assumed for ex-vessel price ($P_y$), number of firms ($X_2$), and the trap license fee.

Such a program may be impractical since the number of traps per firm is not easily regulated. It would be extremely difficult and expensive to regulate the number of traps a firm is fishing. However, the above analysis provides valuable information with respect to the results expected as number of traps per firm varies. Further analysis of implementation and enforcement costs may be warranted before any attempt to manage trap numbers can be a feasible management alternative. Otherwise, this management program may be deferred until more cost-effective means of regulating traps are discovered.

Licensing Firms

This type of management program is similar to licensing traps in that it induces an increased cost per firm through a fee. As firm costs increase only the more efficient fisherman will be able to make a profit and remain in the industry. A program that restricts the number of firms could also require restrictions on number of traps and/or landings but these restrictions were not assumed in this analysis. For illustrative purposes a license fee of $1000 per firm was assumed feasible (Table 16).[1]

[1]Refer to Table 12 for some comparable levels of number of firms ($X_2$) assuming no firm license fee.

Table 16 Analysis of alternative levels for number of firms ($X_2$) assuming traps per firm ($X_1$) equals 700, mean seasonal water temperature ($X_3$) equals 77.591°F, ex-vessel price per pound equals $1.08 and license fee per firm equals $1,000, seasonal study of Florida spiny lobster industry

| | Total Industry | | | | Per Firm | | | |
|---|---|---|---|---|---|---|---|---|
| Number of Firms ($X_2$) | Landings (Q) | Total Revenue (TR) | Total Cost (TC) | Profit (P) | Landings (q) | Total Revenue (TR) | Total Cost (TC) | Profit (P) |
| * 121 | 3,071,519 | 6,101,715 | 1,510,201 | 3,055,616 | 32,000 | 14,560 | 10,901 | 23,500* |
| 175 | 5,058,135 | 5,461,094 | 1,510,175 | 3,544,719 | 10,506 | 31,217 | 10,561 | 10,256 |
| * 211 | 5,511,756 | 5,951,696 | 1,211,771 | 3,615,915* | 20,122 | 28,111 | 10,961 | 17,151 |
| 249 | 5,848,201 | 6,310,055 | 2,725,289 | 3,586,770 | 23,487 | 15,166 | 10,961 | 14,405 |
| 600 | 6,551,437 | 7,077,711 | 6,164,400 | 2,093,312 | 16,184 | 17,696 | 10,561 | 6,731 |
| 400 | 6,760,024 | 7,318,506 | 5,600,500 | 1,840,406 | 13,571 | 14,858 | 10,561 | 3,697 |
| * 856 | 7,064,092 | 7,809,780 | 7,606,534 | 2,846* | 10,153 | 10,965 | 10,561 | 6* |
| 960 | 7,234,621 | 7,813,611 | 10,588,326 | -1,774,715 | 7,609 | 8,009 | 10,961 | -1,872 |

Note Asterisks highlight minimum and maximum profits for firms and/or industry and respective number of firms ($X_2$)

Profits per firm decreased approximately six percent as a result of the $1,000 firm license fee with a range from $23,599 for 121 firms to $4 for 694 firms. Total industry costs increased with the license fee and ranged from $1.3 million for 121 firms to $10.6 million for 966 firms. As a result, the optimum number of firms for maximum industry profit decreased from 225 firms (Table 12) to 211 firms. Total industry landings were reduced by 336,447 pounds due to fewer firms fishing but profit per firm increased by $7,846 because total industry cost was reduced more than total industry revenue. The optimum level of firms for maximum firm profits remained the same at 121 firms as a result of the parallel shift in the industry cost function.

Implications of this analysis are that inputs (traps) used in the fishery would be reduced through rational economic behavior of firms when license fees are charged on a per firm basis. License fees could be set to allow the desired level of firms to maximize profits while harvesting the level of landings desired by management authorities. Licensing firms would appear to be a more manageable and enforceable program for regulating entry of effort into the fishery due to the relatively fewer number of firms than traps in the industry and current entry registration requirements.

The number of licenses issued would be based on desired levels of traps per firm ($X_1$), landings (Q) and expected prices of inputs and outputs. If traps are not regulated, limiting firm numbers does not guarantee that the desired harvest level selected would not be surpassed if the harvest level desired is less than MEY. Depending on the importance of maintaining a desired level of landings, a landings quota could

be attached to the firm license to insure actual landings equal [illegible] desired landings.

Landing Quotas

Under this management alternative each firm would be allocated a percentage of the desired harvest. This percentage could be based on landing records of individual firms and desired harvest levels. The desired harvest level would be announced prior to the opening of the season. For example if each firm of the 400 in the industry were allotted .25 percent of an estimated 5 million pound harvest level, the landings quota per firm would be 12,500 pounds. Profits per firm would be a function of fixed costs plus the number of traps each firm fished since the number of traps per firm determine total cost. In order that efficiency and technological innovation would not be impeded, firms could be allowed to lease part or all of their quotas at the market price. To prevent monopolistic practices from developing a maximum number of quotas per firm could be established.

An alternative to establishing a constant quota per firm would be to vary the quota per firm based on percentages of previous years' landings. For example, percentages could be 60 percent of the first year, 25 percent of the second and 15 percent of the third. This absolute figure is adjusted up or down by a constant percentage per firm depending on the percentage increase or decrease in the estimated sustained yield for the coming season. Other activities such as leasing would not change.

The license fee paid for the quota could be based on estimated profits per firm in conjunction with implementation costs as discussed

previously for the firm licensing program. The quota limits per firm could be set forth as a percentage of each firm's expected total revenues from landings. For example, in Table 12, with 400 firms fishing 700 traps each, profit per firm was $7,734 without any license fee. Assuming that total implementation and enforcement costs of the program would be $800,000 or $2,000 per license, firm profits would be 57.6 percent instead of 77.6 percent of total costs. To enhance the acceptability of the fee charge next year's license fee could be set at 11.3 percent of the previous year's total revenue ($2,000 ÷ $16,320) instead of 25.9 percent ($2,000 ÷ $7,734) of the previous year's profit per firm. Quotas could be offered for sale as a first come, first serve basis or more efficiently by some form of auctioning. If firms exceeded their landing quotas a fine per pound could be levied that would be severe enough to discourage such practices.

The major advantage of a quota system is the assignment of ownership to the resource. Consequently the quota system allows the free market system to operate more easily than would the normal conditions of a common property resource. Free enterprise is conducive to efficiency and technological innovation. As the marketing system operates more freely, less government intervention is required, leading to lower management costs. The quota system also would have the most direct control over landings and, therefore, could be used for controlling landings with minimum delay in situations where MSY has been reached or surpassed.

However, several disadvantages are associated with the quota system. First, the quota system would require accurate information on maximum sustainable yield levels which might necessitate considerable research and management costs. Analytical results in this study show that current

landings are considerably less than MSY than highly accurate estimates of MSY are not required for reasons of over-fishing from a strictly biological point of view. Therefore, it is questionable whether the additional research expense to accurately determine MSY is justified in the short run for management of the spiny lobster industry.

Another possible misconception is that a quota system leads to MEY. This is not necessarily true, particularly with respect to an industry such as the spiny lobster industry where a large percentage of landings are caught in the beginning of the season. With a quota system, effort can just as easily become excessive (meaning, fishing on many traps as without the management program) as fishermen attempt to fill their quotas early before lobsters become scarce. This situation would cause harvesting costs to increase due to the larger number of traps fished.

A Suggested Alternative: Harvest Rebate Program

The harvest rebate program integrates several features of previously discussed programs. In this program effort measured by the number of firms would be limited and would include a license fee. The harvest rebate program offers the flexibility of allowing each firm to maximize landings. Finally, this program allows the market system to regulate harvest since higher license fees will discourage inefficient fishermen. Landings regulated in this manner could be substantially less costly to regulate due to less government intervention than in the more traditional management programs discussed.

These advantages are not to imply that the harvest rebate program is "the approach" for fishery management. Rather, this program was designed to specifically consider problems of the spiny lobster industry,

but in some cases it may be applicable to other fisheries. The following is an illustration of how such a program would operate and the analysis of specific effects on landings, revenues, costs, profits, and optimum input combinations.

Configuration of the Harvest Rebate Program

Establishing this program would begin with a moratorium on all lobster licenses. Using the "grandfather clause" approach the total number of firms would be initially limited to the 1973 level of 400. Next, an accurate recording of the average number of traps fished per firm ($X_1$) would be necessary. This parameter would serve as the foundation for the total program in a given season.

Once the optimum number of traps ($x_1^*$) is established using the firm harvest model (Equation 31), the maximum number of firms required to harvest the desired level of landings (Q) would be determined. Those firms not allowed to enter the industry would receive rebate payments.

Who would receive permits would be a difficult question to answer. One approach is presented here. As an initial program activity, for example, an application deadline could be established for licenses and rebates. At this time a range of probable license fees and rebate payments would be announced. After assessing the ratio of harvesters to rebate receivers a more accurate estimate of license fees and payments would be announced and a three-week period (arbitrary) would be allowed for anyone wanting to change status. The consequences of too many changing status should be made clear to the participants since it could be detrimental to them. For example, too many rebate receivers could reduce individual payments.

Table 17 Median and mean spiny lobster landings per trap for sample of firms classified according to number of traps per firm ($X_1$), economic study of Florida spiny lobster industry

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|
| No. traps firm ($X_1$) | No. firms fishing ($X_2$*) | Landings w/O program ($Q_B$) | Landings with program ($Q_A$) | Total cost per firm ($TC/X_2$) | Profits per firm w/o program ($\pi/X_2$*) | Profits per firm with program ($\pi/X_2$*) | % Δ $\pi/X_2$ Incl Lic. Fee | Maximum state revenue |
| $ | # | lb. | lb. | $ | $ | $ | % | $ |
| 1,800 | 140 | 7,170,570 | 5,810,833 | 13,426 | 5,935 | 25,225 | 325.1 | 2,701,100 |
| 800 | 150 | 8,810,570 | 4,951,626 | 11,116 | 7,273 | 25,441 | 222.3 | 2,522,200 |
| 700 | 171 | 8,553,457 | 4,958,056 | 5,961 | 7,733 | 21,553 | 179.2 | 2,570,000 |
| 510 | 198 | 8,288,487 | 4,955,138 | 9,814 | 7,543 | 19,579 | 144.8 | 2,372,540 |
| 500 | 246 | 5,738,593 | 5,802,577 | 7,651 | 7,822 | 14,342 | 83.8 | 1,596,540 |
| 400 | 328 | 5,253,958 | 4,598,879 | 8,831 | 7,355 | 9,828 | 38.9 | 745,544 |
| 350 | 400 | 4,498,328 | 5,880,376 | (No limited entry program needed since require more firms than currently exist to harvest an MSY equal to 5 million pounds ) | | | | |
| 200 | 400 | 1,410,805 | 4,596,381 | (No limited entry program needed since require more firms than currently exist to harvest an MSY equal to 5 million pounds ) | | | | |

Table 17--Continued

| (10) Maximum license fee | (11) License fee | (12) % of $X_2$ Excl. lic. fee | (13) Gross revenue | (14) Admin. revenue loss where payments | (15) % of Total ind. profit | (16) No. firms rec'd. scheme ($X_2$**) | (17) Gross even harvest per seag (SEC) |
|---|---|---|---|---|---|---|---|
| $ | $ | % | $ | $ | % | No | lb |
| 19,244 | 27,000 | 38.7 | 8,380,200 | 836,000 | 48.0 | 260 | 38.17 |
| 18,100 | 13,500 | 36.7 | 2,106,000 | 331,380 | 25.7 | 244 | 38.4[illegible] |
| 23,800 | 11,500 (11,870) | 20.5 (26.4) | 1,866,500 (2,021,320) | 185,843 (250,363) | 20.4 | 220 | 38.3[illegible] (33.25) |
| 11,436 | 8,500 (10,100) | 24.4 (16.8) | 1,805,000 (1,818,000) | 336,970 (380,970) | 15.9 | 210 | 27.74 (38.64) |
| 6,690 | 5,800 (6,000) | 18.8 (6.3) | 1,330,000 (1,476,000) | 25,412 (271,412) | 12.5 | 154 | 23.43 (25.28) |
| 2,375 | 1,000 (1,535) | 17.3 (5.0) | 328,000 (503,400) | -201,800 (-26,000) | 7.2 | 73 | 18.90 (18.06) |

(No limited entry program needed since require more firms than currently exist to harvest an MEY equal to 5 million pounds.)

(No limited entry program needed since require more firms than currently exist to harvest an MEY equal to 5 million pounds.)

Table 17.--Continued

Note Assumptions (1) Commercial fishermen are profit maximizers, (2) Ex-vessel price, $P_1$ = $1.08 per pound, (3) Desired harvest level for MEY = 5 million pounds (or less defined by input levels), (4) Rebate receivers are maintained at previous levels, (5) Harvesters are maintained at least at previous profit levels, (6) Initial number of firms, $X_2$ = 400; (7) TC = (1,876 + 11.55$X_1$)$X_2$, constant per firm with or without the program; (8) Program is self-supporting

Definition (1) $X_1$ = assumed trap per firm level; (2) $X_2^*$ = maximum number of firms required to harvest MEY, given $X_1$, $X_2 = \dfrac{\hat{X}_2}{K - MEY - \frac{\hat{X}_1}{X_1}}$, (3) $Q_B$ Industry landings before program given $X_2$ = 400 and $X_1$, (4) $Q_A$ = Industry landings after program, given $X_2^*$ and $X_1$, (5) $TC/X_2$ = total cost per firm before and after program, given $X_2$ = 400 and $X_1$, (6) $\pi/X_2$ = profit per firm before program, given $X_2$ = 400 and $X_1$, (7) $\pi/X_2^*$ = profit per remaining firms, $X_2^*$, given $X_1$ (including cost of license fee), (8) Maximum State Revenue = maximum amount total $X_2^*$ could pay in license fees and still maintain previous profit ($\pi$), (9) Maximum License Fee = maximum fee per $X_2^*$ and still maintain previous profit ($\pi$), (10) License Fee = assumed license fee, given $X_2^*$ and $X_1$; (11) State Revenue = total state revenue generated, given license fee, (12) Admin Revenue = remaining revenue for administrative costs after paying rebates, (13) % Δ Ind = percentage change in total industry profit due to program (14) $X_2^{**}$ = number of firms receiving rebate (non-lobster fishing firms), (15) B E C = break-even criterion for firms choosing not to fish this season, defined as average landings per trap.

Refer to Appendix I for computations.

After the three-week deadline licenses and rebate certificates would be issued. Licenses would be paid in installments of 25 percent down, 40 percent by September 15th, since August is usually the best harvesting month; 25 percent by November 1st; and the final 10 percent by the first of the year. The installment plan would closely parallel the timing of the majority of landings. The balance of the license fee would be paid by the first of the year when the majority of the stock has been landed. Rebate payments would be made at the same time and rate.

Alternatively, an auction system could be set up to determine the first round of harvesters and rebate receivers. This has been suggested in the literature in a theoretical framework that essentially equates marginal cost and marginal revenue. This approach could also be used if economic rent is an important consideration of the analysis, a point with which this study has not been concerned.

Regulation of the harvest rebate program should not be any more expensive than the cost of current regulatory programs. All craft and gear must be easily identifiable from the air. More thoughtshould be given to legislation and registries of designated fishing areas prohibiting trespassing of all non-licensed fishermen.

Hypothetical Example and Analysis of Harvest Rebate Program

The structure and bioeconomic status of the spiny lobster industry was analyzed under the harvest rebate program assuming various levels of traps per firm. The levels of traps per firm selected were previously used throughout this study and ranged from 200 to 1000 traps per firm. The results of this analysis are presented in table 17 and include

numbers of harvesters and rebate receivers, profits before and after the program, percentage changes in these profits, revenues and costs to the state, production revenues and costs, and landings with and without the program. The remainder of this section discusses the assumptions of the example and the results of some of the specified levels of traps per firm.

Assumptions

License fees were arbitrarily assigned and were assumed politically acceptable as were administrative costs for implementation and enforcement of the program. Lobster fishermen were assumed to be profit maximizers and thus would select the alternative which was most profitable to their individual firm.

The ratio of harvesters to rebate payment receivers was determined by the minimum number of firms (400 in total) required to land the desired industry harvest level of 5 million pounds for a given level of traps per firm. Rebate receivers were maintained at their previous profit levels. License fees were assigned with several objectives in mind, one of which was to allow harvesters to earn a profit at least five percent higher than their previous level (Column 12).

Another major objective in assigning the level of the license fee was to collect the required revenue to maintain a self-supporting program, assuming administrative costs were not greater than $250,000. In addition, higher license fees were assessed for firms fishing larger numbers of traps since profit percentages per firm increase as the number of traps per firm increases. License fees ranged from $1,000 for firms fishing 429 traps each to $17,000 for firms fishing 1000 traps each.

Total cost per firm was constant regardless of whether a license fee was assessed because the number of traps was assumed constant among firms. Underlying criteria used to arbitrarily assign program costs and revenues were primarily based on the number of fishing firms (harvesters) to be supervised and relative profit levels of these firms.

Number of traps per firm at 700

The maximum number of firms required to harvest the desired industry level of 5 million pounds was estimated to be 172 firms fishing 700 traps each (Table 17). If only this number of firms chose to participate in a harvest rebate program as harvesters, 229 firms would elect not to fish for lobsters and would collect a rebate payment of $7,733 each for the season (Row 3, Columns 6 and 16). These rebates would cost the state $1.8 million ($7,733 x 229). Revenues for harvesters in the program would increase approximately 179.2 percent to $21,593 per firm before license fee charges (Row 3, Columns 7 and 8). At this rate the state could charge a maximum license fee per firm of $13,860 and the firm would be at least as well off than before the program at $7,773 profit per firm (Row 3, Columns 6 and 10). Approximately $2.4 million (Row 3, Column 9) in revenue to the state for rebate payments and management of the industry would be generated.

Assuming the regulatory agency set the license fee at $11,500 to cover rebate payments and program expenses, total profit per firm (harvester), estimated to be $10,093, would be 30.5 percent above profits before the program. Rebate receivers would collect as much as they were making before the program without expending any costs. In addition, these firms could invest their time, skills, and capital elsewhere

Total industry profits would increase (often including license fees) by 13.4 percent. Incomes to fishermen would be improved, resources would be allocated in an efficient manner and the stock of spiny lobsters would be in no danger of over-exploitation.

Number of traps per firm at 618 and 500

Assuming 618 and 500 traps per firm (Rows 4 and 5) profits per firm and total industry profits could also be increased under the harvest rebate program compared with the profit structure prior to the program. However, as the number of traps per firm ($X_1$) would decrease profits for each firm and for the industry would increase (Columns 8, 12, and 15). This situation would occur because the constant rate of increase in total cost per firm would be greater than the rate at which the $MRTS_{X_1X_2}$ would decrease, thus resulting in a less steep increasing total revenue function within the range of data. For example, if a decrease in traps per firm were induced by regulations that limited trap numbers per firm, total cost per trap would decrease. As the number of traps would decrease, $MRTS_{X_1X_2}$ would increase. As $MRTS_{X_1X_2}$ increases along the isoquant (Figure 13) the marginal productivity of a firm decreases, thus requiring more firms in the industry to harvest 5 million pounds. More firms increase total industry costs and thus decrease net returns (profits) to the firms and the industry.

With the harvest rebate program, profits per firm (Column 12) increased 24.4 percent to $9,879 and 19.0 percent to $6,490 for firms fishing 618 and 500 traps, respectively.[1] License fees were assumed at

[1]Profits remaining above the license rent were derived by subtracting Column 11 from Column 7 in Table 17.

$9,500 and $5,000, respectively, to cover rebate payments plus a balance of $136,970 and $25,412, respectively, for administrative costs. At 618 traps per firm (Column 16) 210 firms received a rebate for not fishing (Column 16). Thus the number of firms decreased to 154 as traps per firm decreased to 500 because more firms are needed to harvest the assumed 5 million pounds. As a result of the rebate program, total industry profits increased 15.9 percent with 618 traps per firm and 12.5 percent with 500 traps per firm.

When revenues for administrative costs (Column 14) are not adequate to meet the $250,000 budget assumption license fees would have to increase (Column 11, parenthesis) to a level that will generate the required revenues. For example, if the harvest rebate program was implemented and each firm was allowed to fish 500 traps, the number of firms choosing to fish would be 246 while the number of rebate receivers would be 154. Maximum revenues to the state (Column 9) would be $1,596,540, while program costs for payments to rebate receivers would be $1,204,588 (154 x $7,822). The $5,000 license fee would pay for rebate payments but would leave only $25,412 to administer the program. To remedy this deficit the license fee would need to be increased to $6,000, resulting in a $271,412 budget for administrative costs, excluding rebate payments. This situation would decrease profit per firm from 19.0 to 6.3 percent (Column 12). In the case of 429 traps per firm the required revenues could not be raised without decreasing profit per firm to less than 5 percent. In this case the program was not able to totally support itself (Column 14, Row 5).

Number of traps per firm at 429

At 429 traps per firm the program could not support itself and would experience a $201,560 deficit (Column 14). Only $328,000 of the $529,560 (Column 16 x Column 6) rebate payments could be met with a license fee of $1,000. At this level firm profits would increase 17.3 percent compared with profits outside the program. To help make up the deficit in rebate payments, the license fee would have to be increased to $1,535 which would decrease firm profits to 5.0 percent. Still, a $2b,080 deficit in payments would remain with no budget for administrative costs. Another alternative would be to reduce rebate payments to non-fishermen to a profit level less than what they were making fishing for lobsters. Assuming idle capital and labor resources were invested elsewhere, this may be a feasible alternative.

Number of traps per firm at 350 and 200

If firms were limited to 350 and 200 traps each, all firms would be needed to harvest the 4.5 and 1.4 million pounds, respectively. Since more firms would be required to harvest the desired level of 5 million pounds no management program would be needed since more firms than currently exist are required to harvest MEY (Rows 7 and 8). The average product per firm with 350 traps was 11,241 pounds and with 200 traps was 3,527 pounds. A total of 445 firms with 350 traps each, or a total of 1,41b firms with 200 traps each, could be allowed in the industry to harvest an MEY of 5 million pounds.

Overall summary of analysis (Table 17)

For the range of 200 to 1000 traps per firm selected industry landings were maintained at 5 million pounds under the program, whereas

landings without the program would have ranged from 7.1 to 1.4 million pounds, assuming all 400 firms in the industry fished (Columns 3 and 4). No limit on the number of fishermen was required when fishermen were limited to 350 or less traps each. Firms were limited to 32% if each fished 429 traps and to 140 if each fished 1000 traps (Column 2). Net profits for this group increased in the range from 17.3 to 38.7 percent (Column 12), for 429 and 1000 traps per firm, respectively.

Total program cost ranged from $2.3 million (1000 traps per firm) to $0.5 million (429 traps per firm) and was paid for by license fees ranging from $17,000 for firms fishing 1000 traps each to $1,535 for firms fishing 429 firms each (Columns 11 and 14). Except for a $26,000 deficit assuming each firm fishing 429 traps the program was totally self supporting and firms receiving rebate payments were maintained at their previous incomes. The increase in total industry profit with the program ranged from 7.3 percent assuming 429 traps per firm to 48.5 percent assuming 1000 traps per firm.

Assuming the harvest rebate program would be feasible, individual firms, in many cases, would require a careful evaluation of their operations to determine if a license should be purchased or a rebate payment received. To aid in this decision making process a breakeven criterion was developed as a result of this study.

Breakeven Criterion

Using the time-series data and primary data obtained from the cross-sectional survey, an estimate was developed to provide an indication of which firms might elect to receive payments for not fishing, given the structure of the industry for a particular season. The breakeven

criterion (BEC in Column 17, Table 17) was based on the total cost or total investment of the firm. This information was transformed into average product per trap required to cover operating costs and license fee. Thus a given firm may decide to fish a particular season if the owner feels he is capable of harvesting an amount equal to or greater than the BEC per trap.

To obtain the values for BEC, total cost per firm (Column 5 plus Column 11, Table 17) was divided by the number of traps fished per firm ($X_1$, Column 1, Table 17) which was multiplied times the ex-vessel price ($P_y$). Total firm cost includes the new license fees. The result was the average product per trap ($Q/X_1$) required to cover costs.

To evaluate this criterion, landings per trap derived from the various data used in this study were compared with estimates of BEC for comparable input levels. Landings per trap ($Q/X_1$) for the industry from 1963-73 ranged from a low of 29 pounds in 1973 to a high of 49 pounds in 1966. Landings per trap in the cross-sectional sample ranged from a minimum of 10.68 pounds to a maximum of 54.86 pounds for firms fishing 665 and 401 traps, respectively. The median for the sample was 21.43 pounds for firms fishing 560 traps. The data in Table 18 illustrate the median and mean landings per trap for the given range of number of traps fished ($X_1$) in the sample.

The relatively low values of average landings per trap in the time-series and cross-sectional data may be due to over-capitalization in traps since no limits exist on traps. Estimated average landings per trap ($Q/X_1$) with the harvest rebate program are higher than comparable

Table 18. Median and mean spiny [illegible] trap for sample of firms classified according to number of traps per firm ($X_1$), economic study of Illinois spiny lobster industry

| Landings per trap | Number of traps fished per firm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | <200 | 200-399 | 400-499 | 500-599 | 600-699 | 700-899 | >900 | Total |
| Median | 21.80 | 22.67 | 17.07 | 24.10 | 26.28 | 19.33 | 16.32 | 21.43 |
| Mean | 26.02 | 22.92 | 27.45 | 24.10 | 22.54 | 19.26 | 16.93 | 21.37 |
| Observations | 3 | 4 | 3 | 2 | 5 | 5 | 3 | 25 |

breakeven estimates (BEC) as illustrated in Table 19.[1] Estimated landings per trap ($Q/X_1$) were derived by dividing the total number of firms in the industry after the harvest rebate program into estimated landings after the program. Since the breakeven criterion of landings per trap was below the estimated actual landings per trap the firm would have some flexibility in its decision on whether to fish or not.

BEC ranged from 16.09 pounds per trap for 429 traps per firm to 28.17 pounds per trap for 1,000 traps per firm. The figures in parentheses (Table 19) represent BEC after adjustments in the license fee were made to compensate for deficit program costs illustrated in Table 17 (parentheses in Column 11). Estimated landings per trap ranged from 35.02 to 42.54 pounds per trap, thus resulting in a range of 54 to 21

[1] $Q/X_1$ can be represented notationally as

$$Q/X_1 = \frac{Q_A}{(X_2^*)(X_1)}$$

where,

$Q/X_1$ = estimated average landings per trap,

$Q_A$ = estimated landings with harvest rebate program (Column 4, Table 17),

$X_2^*$ = maximum number of firms required to harvest $Q_A$, given $X_1$ (Column 2, Table 17),

$X_1$ = assumed number of traps per firm (Column 1, Table 17).

Table 19. Analysis of landings per trap required to break-even under the harvest rebate program for alternative levels of traps per firm ($X_1$), economic study of Florida spiny lobster industry

| | Number of traps per firm | | | | | |
|---|---|---|---|---|---|---|
| | 1,000 | 800 | 700 | 618 | 500 | 425 |
| $Q/X_1$ | 35.79 | 40.00 | 41.74 | 42.54 | 40.67 | 35.02 |
| BEC | 28.17 | 28.49 | 28.39 (32.25) | 27.74 (28.64) | 23.43 (25.28) | 16.90 (18.06) |
| % Δ | 21.29 | 28.78 | 31.98 | 34.79 | 42.39 | 54.05 |
| Max. No. Firms | 140 | 156 | 171 | 190 | 246 | 328 |

Note: $Q/X_1$ is estimated landings per trap under harvest rebate program. BEC is landings per trap required to break-even under price and cost assumptions of harvest rebate program (break-even criterion). % Δ is the percentage difference in $Q/X_1$ and BEC. Max. No. Firms is the maximum number of firms allowable in the industry for given levels of traps per firm under the harvest rebate program.

percent above BEC, respectively. For example, at 700 traps per firm BEC was 31.98 percent below the estimated average landings per trap. At 500 traps BEC was 42.39 percent below ($Q/X_1$) and at 425 traps BEC was 54.05 percent below $Q/X_1$. As traps per firm decrease, the difference between estimated landings per trap and the breakeven level became larger. This is due to the law of diminishing marginal rate of returns resulting in an increasing marginal product for a trap as the number of traps per firm decreases. Thus the program does appear realistic when compared with expected changes in the industry structure and performance as a result of the harvest rebate program.

One question that may be of concern about the harvest rebate program is, "What happens if firms do not select the appropriate plan designed for them?" Several problems could cause the estimated number of rebate receivers and harvesters to change.

First, the estimation of traps per firm could be reevaluated. As previously mentioned, considerable effort and funds could be spent to accurately estimate average traps fished per firm. Second, the license fee could be too high if too many firms have applied for a rebate. On the other hand, the license fee could be too low if too many firms have applied for a license. In the short-run, the rebate could be increased before the suggested three-week deadline if too many license applications were received. If too many applications were received for rebates the license fee could be lowered during this period.

Finally, another problem might be that estimates of input and output prices could be different from various sectors of the industry. The state should be prepared to absorb the inaccuracies of the program should the ratio still be out of proportion after short-run remedies have failed. Program adjustments could be made the following year based on experiences in the previous year(s).

In summary, the harvest rebate program is offered as a non-traditional alternative. Its features include increased profits to the industry and firm, depending on estimated levels of traps per firm. Since inputs would be reduced, current over-capitalization would be reduced, allowing more efficient harvesting through such activities as economies of scale. More importantly the rebate program would allow the fishermen to make the decision of whether or not to fish. It could also lead to improved stock and fishing grounds since fewer traps and craft would be employed in the harvesting process of the industry.

## CHAPTER VII

## SUMMARY AND CONCLUSIONS

Florida's spiny lobster (*Panulirus argus*) industry achieved tremendous growth during the past two decades and is presently the second most important fishery in the state in terms of dockside value of landings. Spiny lobster landings in Florida exceeded 11 million pounds in 1973 with an estimated retail value of over $40 million. Florida landings represent approximately 98 percent of total U.S. landings.

The tremendous growth in landings is a result of a disproportionate increase in inputs into the fishery. Number of spiny lobster firms, number of traps, and size of firms (gross tonnage) have increased throughout the past two decades. The rate of increase has been greatest since 1965. The increase in number of firms and total traps fished was 80 percent and 242 percent, respectively, between 1965 and 1972. During this same period total industry landings increased only 16 percent, while landings per firm actually decreased by approximately 60 percent. An increase in the retail price of lobster tails from $1.50 per pound in 1960 to over $9.00 per pound in 1975 has induced the growth in inputs employed in the spiny lobster harvesting process. Thus the immediate problem addressed in this dissertation was that of answering economic questions relative to industry growth. 'Over investment' in capital (gear and craft) and labor (fishermen) has occurred in an effort to harvest a relatively fixed supply. The increased fishing effort in

the fishery also raises concern about the possibility of "[illegible] exploitation" of the fishery stock.

The primary objectives of this study were to (a) evaluate the extent of fishing effort in the industry and determine both the maximum sustainable yield and the maximum economic yield, and (b) analyze alternative management programs which would allow for a more efficient utilization of the fishery stock. To achieve these objectives, two analytical models were developed for the Florida Keys spiny lobster fishery. A bioeconomic model was estimated for a time period in which the biological stock was allowed to vary. The second model (firm harvest function) was estimated for a given stock of lobster resources. With these two models the impacts of selected management programs were analyzed by simulating the industry with respect to estimated optimum levels of inputs.

The scope of the study was defined to include only the Florida spiny lobster fishery. The data for the empirical analysis represented Monroe County, Florida, since approximately 80 percent of Florida domestic landings are landed in Monroe County.

Theoretical considerations and industry data availability required that the bioeconomic model be estimated as a function of traps per firm, number of firms employed in the industry, and mean seasonal water temperature. The mathematical form of the model was a reciprocal equation which represented behavior consistent with suggested theory and the current status of the industry with respect to sustainable yield and present management policies. Annual time-series data from 1963 to 1973 were used for estimation. The overall explanatory power was high and each coefficient was statistically significant in the model.

The firm harvest function was estimated from a cross-sectional sample of lobster firms. Spiny lobster fishermen selected by a statistically designed sample were interviewed in 1974 concerning specific aspects of the spiny lobster harvesting process. This data was used to analyze the lobster harvest function for a given stock level on a per firm basis. A Cobb-Douglas functional form model was used to relate firm landings to the number of traps fished and fishing intensity. Fishing intensity was measured as percentage of traps pulled per week, number of weeks fished, and size of the craft. Location of fishing grounds was entered in the model to adjust for area differences in fishing conditions. All variables with the exception of one location variable were highly statistically significant. The cross-sectional harvest model was used to estimate the profit maximizing level of traps per firm. This value was then substituted into the bioeconomic industry function for traps per firm to complete the industry analysis.

Maximum sustainable yield for the industry was approximated by observing the range of estimated maximum industry landings as traps per firm and then firms were increased to practical feasible limits. While one input was varied the other was held constant at actual mean, minimum, and maximum levels employed in the industry. The estimated range in maximum sustained yield was between 5.9 to 8.9 million pounds. For the purposes of the study, 8 million pounds was defined as an extreme estimate of maximum sustainable yield while 6 million pounds was defined as a conservative estimate.

Maximum economic yield was estimated for the industry allowing both traps per firm and number of firms to be simultaneously determined such that maximum economic profit would be attained. Maximum economic yield

was estimated to [illegible] pounds. The optimum level of firms was determined to be 213 [illegible] fishing 795 traps. Estimates were based on 1973-74 ex-vessel prices ($1.08 per pound) and 1973-74 total costs per firm and per trap. These optimum levels would require a reduction of 47 percent in number of firms and a slight reduction of 1,836 traps in the total industry from 1973 levels. Total industry landings would be increased approximately 16 percent over 1973-74 season harvest. Estimates will change depending on relative changes in the cost of production and product prices. As usual, maximum economic yield was less than the predicted maximum sustained yield.

Recognizing that maximum economic yield may not be the immediate goal for management because of the political and social consequences of extreme adjustments in the short-run, further analyses were completed. The analyses considered (a) parameters from the firm harvest function which represented current stock levels and thus would be relevant for current management programs and (b) alternative levels of one input while holding the other input at politically realistic levels. These analyses provide information to regulatory agencies which could be used in assessing benefits and costs of alternative management programs.

Fewer than the optimum number of firms would be allowed to enter the industry if the major objective of the regulatory agency was to maximize average net return per firm. This objective was evaluated using value marginal product analysis with respect to the industry harvest function. The results showed only 121 firms could be allowed to enter the industry assuming 700 traps per firm and 1973-74 factor costs and product price. Total industry profits would be maximized with 225 firms using value marginal product analysis, thus defining the range of

number [illegible] based on rational profit maximization [illegible] agency. As a result, total industry [illegible] range from [illegible].87 million pounds with 121 firms to 5.65 million pounds with 225 firms.

Considerable substitution between number of traps per firm and number of firms can be made without changing the level of landings thus providing numerous policy alternatives. Rates of substitution between numbers of traps per firm and number of firms were determined. Beyond 400 firms substantial increases in number of firms would be required to maintain landings due to a reduction in traps per firm. An analysis of the possible range of combinations of traps per firm and number of firms where profits are positive was presented with the use of isoquant map. The conclusion was that profits would not be possible if more than 900 firms would enter the industry, nor would it be feasible for a firm to fish with less than 75 traps.

For purposes of this study "management" was defined to include maintaining current levels of inputs, as well as increasing or decreasing their levels. Traditional programs were analyzed by simulating the behavior of the spiny lobster fishery under programs which would license traps, license firms and issue landing quotas. Finally, an alternative management scheme, entitled "harvest rebate program," was suggested. This program would incorporate aspects of the traditional system.

Programs were analyzed under the previously stated factor costs and product price assumptions. The desired value for landings was assumed to be 5 million pounds. Seven hundred traps were determined as optimum for 1973-74 stock levels for profit maximization.

Licensing of traps appears feasible in a theoretical framework if performed in conjunction with some form of "grandfather clause" legislation. The objective would be to increase costs per trap to a level where the level of traps fished would be such that the value of the marginal product would be equal to the marginal factor cost of a trap. Data for this analysis was obtained from the survey of spiny lobster firms and results showed that typical firms in the industry would be required to reduce number of traps fished. Assuming 400 firms in the industry, firm and industry profits are maximized at 357 traps per firm. No profits are returned if a firm fishes less than 207 traps. Furthermore, if less than 400 traps per firm are fished, no regulation of traps would be needed to maintain the desired 5 million pound level for landings. Licensing of traps from a pragmatic standpoint, however, may not be feasible since policing the number of traps per firm would be difficult and expensive to regulate.

The firm licensing program was essentially based on the theoretical motive of increasing marginal factor costs of the firm to a level where the value of the marginal product of an additional firm added to the industry is equal to the marginal factor cost of the firm. Such a program may or may not limit the number of traps fished and/or landings. Seven hundred traps fished and a $1000 license fee were assumed per firm for the simulated example.

The analysis showed profit per firm was maximized with 121 firms, while total industry profit was maximized with 211 firms in the industry. Total landings were 3.87 million pounds for 121 firms compared with 5.51 million pounds for 211 firms in the industry. If more than 694 firms entered the industry no profits were earned. If each firm

fished 700 traps, so more than 175 firms could be allowed in the industry in order to maintain a desired harvest level of 5 million pounds

Licensing firms appeared to be a more manageable program for regulating entry of effort into the fishery than licensing traps since a much smaller number of units (number of firms) would have to be regulated The number of licenses issued would be based on the regulatory agency's objectives and selected parameters for traps per firm, landings, and expected prices of inputs and outputs. Furthermore, if traps were not regulated, limiting the number of firms would not guarantee that the desired level of landings would be achieved.

Landing quotas could be useful as a management tool for expedient adjustments to precisely control industry landings Since current landings were less than the estimated range of maximum economic yield levels precise control of landings was not viewed as an immediate concern in the Florida spiny lobster fishery Consequently, an example of the industry structure and behavior regulated through landing quotas was not simulated. However, a quota fee could be assessed in a similar manner to the firm licensing program. The major advantage of the quota system would be that it would allow the harvesting process to operate freely to optimally combine inputs Free enterprise is conducive to efficiency and technological innovation, which could lead to reduced total industry costs in the long run

Conversely, disadvantages of the quota system are (a) that an accurate estimation of maximum sustainable yield would be needed which could generate high research costs, (b) maximum economic yield would not necessarily be attained since the incentives of over capitalization still remain, and (c) the fisherman's motivation due to dreams of 'the

[illegible] would be desir[illegible] [illegible] ere limited to a predetermined harvest level

An alternative approach to management, the "harvest rebate program," was offered for further consideration. This program integrated several features of the previously discussed traditional management programs. Effort in the form of firms would be limited and license fee would be required. The harvest rebate program offers the flexibility of allowing each firm to maximize landings. Finally, this program would allow the market system to regulate harvest since higher license fees should discourage inefficient fishermen. Landings regulated in this manner could be substantially less costly to regulate due to less government intervention than would be the case in the more traditional management programs discussed.

The harvest rebate program was analyzed simulating the industry behavior under various levels of traps per firm. License fees were ranged from $17,000 to $1,000 per firm, with the optimal number of firms ranging from 140, each fishing 1,000 traps, to 328, each fishing 429 traps. Those fishermen choosing not to fish would receive a rebate payment equivalent to the average firm profit without the program for a specified level of inputs. The increase in profit per firm for those fishermen electing to pay the license fee ranged from 38.7 percent with 140 firms in the industry to 17.3 percent with 328 firms in the industry. Profits for each of the 400 firms before the management program ranged from $5,935 for firms fishing 1,000 traps to $7,943 for firms fishing 618 traps. Maximum revenue to the state, given the assumptions of the analysis, ranged from $745,544 for 328 firms to $2,701,160 for 140 firms.

Finally, a breakeven criterion was developed to help the fisherman decide whether he should fish under the harvest rebate program, or elect not to fish and receive a rebate payment. The criterion was in terms of the minimum pounds per trap necessary to maintain a profit level equal to or greater than the profit level without the program. The conclusion was that a firm must harvest an average of 16.90 pounds per trap (assuming 32% firms, each fishing 429 traps) to 28.45 pounds per trap (assuming 156 firms, each fishing 800 traps) before it would be economically feasible to purchase a license to fish. Thus, fishermen participating in the program would operate with considerable flexibility, firm and industry profits would be equal to or greater than would be the case without the program, and the program would be totally self-supporting.

# APPENDICES

# APPENDIX A

Table A1  Spiny lobster landings and dollar value: Florida and U.S., 1952–73, economic study of Florida spiny lobster industry

| | U.S. | | | Florida | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 1,000 Pounds | 1,000 Dollars | Cents per Pound | Pounds | Dollars | Cents per Pound | Percent of U.S. Pounds | Percent of U.S. Dollars |
| 1952 | 1 111 | 110 | 30 6 | 1,532 100 | 481 100 | 20 0 | 88 | 51 |
| 1953 | 1 141 | 151 | 32 4 | 1 941 000 | 398 000 | 20 0 | 1 | 33 |
| 1954 | 1,640 | 820 | 29 6 | 1,111,100 | [illegible] | 21 8 | 68 | 31 |
| 1955 | 1,234 | 963 | 30 1 | 1 785 100 | [illegible] | 21 0 | 73 | 51 |
| 1956 | 1,560 | 1,210 | 31 1 | 1,111 000 | 415 057 | 21 5 | 11 | 68 |
| 1957 | 1 681 | 1 500 | 30 0 | 4 039 800 | 1 113 513 | 11 8 | 56 | 11 |
| 1958 | 1 588 | 1 26 | 34 1 | 1,134 381 | 838 851 | 28 5 | 25 | 68 |
| 1959 | 1 003 | 1,213 | 34 5 | 1 130 711 | 954 805 | 30 0 | 18 | 15 |
| 1960 | 3 110 | 1,314 | 31 8 | 2 [illegible] 540 | [illegible] | 38 0 | 37 | 81 |
| 1961 | 1 231 | 1,303 | 30 6 | 1 665,638 | 900 345 | 36 6 | 11 | 77 |
| 1962 | 3,556 | 1,561 | 42 8 | 2 101 508 | 111 111 | 38 7 | 35 | 18 |
| 1963 | 4 111 | 1 100 | 13 0 | 3,311 134 | [illegible] | 21 5 | 26 | 70 |
| 1964 | 4 660 | 1 800 | 18 0 | 3 811 130 | [illegible] | 11 0 | 32 | 81 |
| 1965 | [illegible] | [illegible] | 38 1 | 3 113 208 | [illegible] | 36 5 | 81 | 88 |
| 1966 | 1 011 | 2,662 | 40 5 | 5,316 216 | 2,[illegible] | 18 1 | 81 | 84 |
| 1967 | 1,010 | 1,173 | 64 5 | 8 411 [illegible] | 1 12 116 | 21 5 | 11 | 88 |
| 1968 | 3 110 | 1 361 | 11 8 | 6 [illegible] | 650 8 | 11 6 | 11 | 23 |
| 1969 | 8,791 | 1,500 | 11 8 | 7 [illegible] | 1 211 [illegible] | 60 5 | 71 | 83 |
| 1970 | 10,[illegible] | 1 112 | 81 2 | [illegible] | [illegible] | 10 8 | 71 | 94 |
| 1971 | 8 1 0 | 1 091 | 43 3 | [illegible] | [illegible] | [illegible] | 8 | 88 |
| 1972 | 5 0 1 | [illegible] | 49 [illegible] | [illegible] | 10 [illegible] | 42 [illegible] | 91 | 86 |
| 1972[a] | 11 95 | 1 11[illegible] | 152 | [illegible] | 10 111 125 | [illegible] | [illegible] | 91 |
| 1973 | 9 011 | 1 561 | 10 0 | [illegible] | 1 2[illegible] | 15 [illegible] | 95 | 81 |
| 1973[b] | 910 | [illegible] | 15 1 | [illegible] | 1 101 [illegible] | [illegible] | 31 | 85 |

Source: Fishery Market News Reports [illegible] Fisheries [illegible] United States [illegible] Government Printing Office, Washington, D.C. Annual [illegible]

National Marine Fisheries Service [illegible] Current Fisheries Statistics [illegible] Monthly and annual issues [illegible]

Note: [illegible]

[a]"Out of country landings" [illegible] 1972 were 26 [illegible]

The following data [illegible] obtained from [illegible] Southeast Fisheries Center [illegible]

| Year | Key West Pounds | Key West Dollars | [illegible] Pounds | [illegible] Dollars | Total Pounds | Total Dollars | [illegible] per pound |
|---|---|---|---|---|---|---|---|
| 1972 | 5[illegible] 156 | 111 [illegible] | 232 205 | [illegible] | 15 [illegible] | 105 [illegible] | 100 3 |
| 1973 | 1 350 151 | 1 150 311 | 103 171 | 209 111 | [illegible] | 2 [illegible] 508 | 15.3 |

[b]Estimated by 11 001 x 16 011 = 33 [illegible]

Table 81. Spiny lobster capital and labor inputs Florida west coast, 1952-33, economic study of Florida spiny lobster industry

| Year | Fishermen | | | | Boats | Vessels | | Traps | Firms | Traps Per Firm |
|---|---|---|---|---|---|---|---|---|---|---|
| | On Vessels | On Shore Regular | On Shore Casual | Total | No | No. | Gross Tonnage | No | No | No |
| 1952 | 0 | 71 | 0 | 31 | 56 | 0 | 0 | 4,500 | 54 | 83 |
| 1953 | 0 | 30 | 0 | 30 | 55 | 0 | 0 | 5,500 | 55 | 110 |
| 1954 | 4 | 87 | 22 | 115 | 77 | 2 | 13 | 11,[illegible] | 33 | 140 |
| 1955 | 4 | 61 | 10 | 15 | 81 | 3 | 14 | 13,200 | 63 | 203 |
| 1956 | 23 | 88 | 18 | 125 | 53 | 14 | 104 | 16,315 | 31 | 236 |
| 1957 | 49 | 138 | 10 | 193 | 85 | 25 | 135 | 31,320 | 100 | 201 |
| 1958 | 33 | 105 | 8 | 143 | 86 | 13 | 142 | 31,[illegible] | 105 | 231 |
| 1959 | 30 | 174 | 20 | 224 | 159 | 13 | 156 | 33,[illegible] | 135 | 291 |
| 1960 | 29 | 193 | 18 | 238 | 152 | 15 | 131 | 55,550 | 168 | 315 |
| 1961 | 32 | 110 | 11 | 313 | 124 | 16 | 165 | 38,[illegible] | 150 | 339 |
| 1962 | 40 | 193 | 7 | 325 | 151 | 20 | 213 | 58,350 | 171 | 341 |
| 1963 | 54 | 233 | 12 | 305 | 152 | 35 | 261 | 60,850 | 186 | 323 |
| 1964 | 68 | 238 | 104 | 410 | 215 | 34 | 308 | 33,[illegible] | 2[illegible] | 393 |
| 1965 | 56 | 305 | 26 | 305 | 180 | 26 | 308 | 89,[illegible] | 316 | 615 |
| 1966 | 104 | 308 | 13 | 515 | 210 | 30 | 635 | 34,570 | 360 | 370 |
| 1967 | 153 | 330 | 24 | 593 | 230 | 35 | 1149 | 91,[illegible] | 299 | 303 |
| 1968 | 135 | 316 | 12 | 545 | 135 | 133 | 3423 | 99,500 | 332 | 363 |
| 1969 | 184 | 355 | 23 | 455 | 176 | 52 | 2195 | 95,955 | 268 | 353 |
| 1970 | 201 | 331 | 13 | 635 | 315 | 135 | 5534 | 150,050 | 353 | 545 |
| 1971 | 354 | 359 | 30 | 663 | 195 | 142 | 4184 | 143,833 | 333 | 436 |
| 1972 | 550 | 352 | 53 | 320 | 238 | 155 | 5036 | 124,450 | 393 | 445 |

Source: National Marine Fisheries Service, Fishery Statistics of the United States, (Formerly Bureau of Commercial Fisheries), U.S. Government Printing Office, Washington D.C., Annual Issues, 1952-32.

Table C1 Input/Output relationships, Florida west coast, 19[illegible] [illegible] economic study of Florida spiny lobster industry

| Year | Pounds Per Trap | Dollars Per Trap | Pounds Per Firm | Dollars Per Firm |
|---|---|---|---|---|
| 1952 | 213 | 53 | 17,717 | 4,429 |
| 1953 | 134 | 27 | 15,887 | 3,177 |
| 1954 | 62 | 14 | 9,896 | 2,177 |
| 1955 | 93 | 21 | 18,802 | 4,324 |
| 1956 | 137 | 35 | 32,408 | 8,363 |
| 1957 | 154 | 42 | 30,957 | 8,437 |
| 1958 | 100 | 29 | 22,205 | 6,218 |
| 1959 | 78 | 23 | 14,987 | 4,421 |
| 1960 | 39 | 15 | 12,674 | 4,879 |
| 1961 | 54 | 18 | 15,010 | 5,148 |
| 1962 | 42 | 16 | 14,238 | 5,436 |
| 1963 | 46 | 18 | 14,896 | 5,808 |
| 1964 | 39 | 16 | 11,473 | 4,885 |
| 1965 | 49 | 28 | 20,301 | 11,423 |
| 1966 | 49 | 22 | 13,672 | 6,191 |
| 1967 | 30 | 18 | 9,154 | 5,601 |
| 1968 | 40 | 29 | 14,415 | 10,398 |
| 1969 | 48 | 34 | 17,360 | 12,406 |
| 1970 | 46 | 27 | 20,332 | 12,131 |
| 1971 | 32 | 28 | 14,068 | 12,145 |
| 1972 | 20 | 21 | 13,069 | 14,003 |

## APPENDIX D

## CROSS-SECTIONAL DATA COMPUTATIONS

Definitions:

$x_1$ = (TR), average number of traps fished for the season

$x_2$ = (FWK), average number of rounds per week for the season.

$x_3$ = (WK), number of weeks fished during season (36 maximum)

$x_4$ = (LOWD), size of hull in square feet; computed as hull length (LO) times hull width (WD).

$x_5$ = (DU), dummy variable for upper Keys; DU = 0 if included and 1 if excluded.

$x_6$ = (DL), dummy variable for lower Keys, DL = 0 if included and 1 if excluded.

i = months, 1, 2, . . . 8 (August - March)

PULL = pulling a trap out of the water once (also termed hauling)

TOTAL PULLS = total number of times a trap was pulled (P) out of the water (could be same or different trap(s))

ROUND = pulling all traps fished, once.

$R_i$ = total rounds per month i

TOTAL ROUNDS = total number of times <u>all</u> traps fished were pulled (R).

SET PERIOD = length of time a trap sets between pulls (SP)

$SP_i$ = set period for month i

$D_i$ = days per month i.

LO = hull length

WD = hull width.

$T_i$ = traps fished in month i

DATA COLLECTED (or known): $T_i$, $SP_i$, $D_i$, $x_3$, LO, WD, $x_5$, and $x_6$.

DERIVATIONS

$$x_1 = \frac{P}{R} \tag{1}$$

$$P = \sum_{i=1}^{8} (T_i)\ (K_i) \tag{2}$$

$$R_i = \frac{DI}{SP_i} \tag{3}$$

$$R = \sum_{i=1}^{8} R_i \tag{4}$$

$$x_2 = \frac{R}{x_3} \tag{5}$$

$$x_4 = (LO)\ (WD) \tag{6}$$

Table 81. Spiny Lobster landings and dollar values Florida east and west coasts, and Monroe County, 1951-71 | commercial study of Florida spiny lobster fishery

| Year | FLORIDA | | | EAST COAST | | | WEST COAST | | | % Florida | | MONROE CO. ONLY | | | % East Coast | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pounds | Dollars | c/lb | Pounds | Dollars | c/lb | Pounds | Dollars | c/lb | Pounds | Dollars | Pounds | Dollars | c/lb | lb | Dollars |
| 1951 | 1,712,760 | 1[illegible],[illegible] | 77.0 | 737,780 | 161,777 | 21.9 | 754,189 | 217,177 | 28.8 | 77 | 77 | 741,397 | NA | NA | 71 | NA |
| 1952 | 1,[illegible] | [illegible] | 80.0 | 1,111,[illegible] | 716,[illegible] | 20.7 | [illegible] | 1[illegible],[illegible] | 21.0 | 71 | 71 | 715,[illegible] | NA | NA | 74 | NA |
| 1953 | [illegible],186 | 177,186 | 41.9 | 7,211,[illegible] | 772,177 | 27.7 | 7,[illegible],[illegible] | 177,[illegible] | 21.0 | 71 | 77 | 121,777 | NA | NA | 100 | NA |
| 1954 | 7,541,[illegible] | 1,[illegible],777 | 77.0 | 1,712,[illegible] | 7,[illegible],171 | 27.7 | 7,118,[illegible] | 379,[illegible] | 22.0 | 57 | 57 | 7,[illegible],177 | NA | NA | 100 | NA |
| 1955 | 7,111,[illegible] | 7,7[illegible] | 76.5 | 717,[illegible] | 721,[illegible] | 27.7 | 7,[illegible],[illegible] | 501,[illegible] | 11.7 | 74 | 77 | 7,157,817 | NA | NA | 100 | NA |
| 1956 | 7,[illegible],[illegible] | 1,171,[illegible] | 71.7 | 771,[illegible] | [illegible],177 | 77.7 | 1,188,[illegible] | 717,771 | 71.7 | 77 | 80 | 7,[illegible],[illegible] | NA | NA | 703 | NA |
| 1957 | 1,[illegible],[illegible] | 716,[illegible] | 27.7 | 712,[illegible] | 1[illegible],[illegible] | 28.1 | 7,[illegible],[illegible] | [illegible],[illegible] | 24.0 | 7 | 10 | 1,[illegible] | NA | NA | 709 | NA |
| 1958 | 1,[illegible],171 | 71,[illegible] | 72.7 | 74,[illegible] | [illegible],[illegible] | 12.7 | [illegible],[illegible] | 717,[illegible] | 29.7 | 87 | 81 | 1,[illegible] | NA | NA | 700 | NA |
| 1959 | 7,717,[illegible] | 1,[illegible],[illegible] | 58.7 | 717,[illegible] | [illegible],[illegible] | 19.0 | 2,[illegible],[illegible] | 71,[illegible] | 77.7 | 13 | 18 | 2,11[illegible],[illegible] | 713,444 | 77.7 | 700 | 700 |
| 1960 | 7,771,[illegible] | 717,771 | 36.7 | 771,[illegible] | 778,[illegible] | 11.7 | 1,[illegible],[illegible] | 7,[illegible],[illegible] | 77.7 | 78 | 77 | 1,[illegible],[illegible] | 720,171 | 1[illegible].7 | 700 | 700 |
| 1961 | 1,[illegible],[illegible] | 1,111,[illegible] | [illegible] | 871,[illegible] | 717,[illegible] | 38.0 | 1,[illegible],[illegible] | 7,[illegible] | 77.7 | [illegible] | 10 | 2,[illegible],[illegible] | [illegible] | [illegible] | 107 | 100 |
| 1962 | 1,[illegible],171 | 1,[illegible],[illegible] | 17.7 | 717,[illegible] | 171,[illegible] | 77.1 | 1,[illegible],[illegible] | 7,[illegible],[illegible] | 17.0 | 71 | 77 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 17.0 | 10 | 107 |
| 1963 | 1,[illegible],[illegible] | 1,[illegible],[illegible] | 77.7 | [illegible],[illegible] | 7[illegible],[illegible] | 4.0 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 42.7 | 78 | 78 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 7 | [illegible] | 107 |
| 1964 | 2,[illegible],[illegible] | 1,[illegible],[illegible] | 1.6 | 7,[illegible],[illegible] | 111,[illegible] | [illegible] | 4,[illegible],[illegible] | 7,[illegible],[illegible] | 71.7 | 71 | 71 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | [illegible] | [illegible] | 107 |
| 1965 | 1,[illegible],[illegible] | 2,[illegible],[illegible] | 24.7 | 7,[illegible],[illegible] | 817,[illegible] | 11.7 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 77.7 | 68 | 77 | 1,[illegible],[illegible] | 1,[illegible],[illegible] | [illegible] | [illegible] | [illegible] |
| 1966 | 7,[illegible],[illegible] | [illegible],[illegible] | 71.7 | 7,[illegible],[illegible] | 1,717,[illegible] | 71.1 | 7,[illegible],[illegible] | 1,714,[illegible] | 71.1 | 77 | 87 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | [illegible] | [illegible] | [illegible] |
| 1967 | 1,[illegible],[illegible] | 1,[illegible],[illegible] | 87.7 | 1,[illegible],[illegible] | 7,737,[illegible] | 76.7 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 71.5 | 87 | 87 | 4,[illegible],[illegible] | 1,[illegible],[illegible] | [illegible] | 48 | [illegible] |
| 1968 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 17.0 | 7,[illegible],[illegible] | [illegible],[illegible] | 17.0 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 71.7 | 69 | 79 | 7,[illegible],[illegible] | 7,[illegible],[illegible] | 7.1 | 17 | [illegible] |
| 1969 | 7,[illegible],[illegible] | 2,[illegible],[illegible] | 86.0 | 1,[illegible],[illegible] | 7,[illegible],[illegible] | 75.7 | 7,[illegible],[illegible] | 7,[illegible],[illegible] | 77.1 | 58 | 58 | 4,[illegible],[illegible] | 4,[illegible],[illegible] | 71.1 | 91 | [illegible] |
| 1970 | 10,[illegible],[illegible] | 7,[illegible],[illegible] | 71.1 | 7,[illegible],[illegible] | 7,777,[illegible] | 77.7 | 4,[illegible],[illegible] | 7,[illegible],[illegible] | 77.7 | 47 | 11 | NA | NA | NA | NA | NA |
| 1971 | 7,[illegible],[illegible] | 1,[illegible],[illegible] | 71.1 | 7,[illegible],[illegible] | 7,[illegible],[illegible] | 77.7 | 7,[illegible],[illegible] | 7,[illegible],[illegible] | 71.1 | 55 | 77 | NA | NA | NA | NA | NA |
| 1951-4 | 1,717,177 | 71,111,417 | 77.1 | 7,777,780 | 7,[illegible],[illegible] | 77.7 | 7,147,[illegible] | 7,[illegible],[illegible] | 77.7 | 77 | 77 | 7,[illegible],[illegible] | 5,[illegible],[illegible] | 71.7 | 71 | 77 |
| 1951-71[a] | 11,711,[illegible] | 71,171,[illegible] | 70.[illegible] | 7,721,777 | 7,[illegible],[illegible] | 102.7 | 7,710,[illegible] | 7,971,[illegible] | 106.0 | 58 | 77 | 7,742,[illegible] | 77 | NA | 77 | |

[a]Includes our 78 season landings. See Footnote a, Table A1, Appendix 7

[illegible] 1. Spiny lobster landings in Florida [illegible] waters, 1964-73, economic study [illegible] industry

| Year | Total Florida Landings | Florida Landings From Domestic Waters | Florida Landings From Foreign Waters | |
|---|---|---|---|---|
| | Quantity (Pounds) | Quantity (Pounds) | Quantity (Pounds) | Percent of Florida |
| 1964 | 3,631,100 | 2,632,547 | 998,553 | 27.6 |
| 1965 | 5,714,100 | 4,719,847 | 994,253 | 17.4 |
| 1966 | 5,350,000 | 3,151,150 | 2,198,850 | 41.1 |
| 1967 | 4,414,000 | 1,915,676 | 2,498,324 | 56.6 |
| 1968 | 6,155,000 | 2,880,540 | 3,274,460 | 53.2 |
| 1969 | 7,582,000 | 4,086,698 | 3,485,302 | 46.1 |
| 1970 | 9,862,462 | 6,745,924 | 3,116,538 | 31.6 |
| 1971 | 8,205,803 | 4,669,102 | 3,536,701 | 43.1 |
| 1972 | 11,986,221[a] | 5,488,338 | 6,497,883[a] | 54.2 |
| 1973 | 12,676,188[a] | 6,621,122 | 6,055,066[a] | 47.8 |

Source: Foreign water landings obtained from unpublished data collected by the Statistical Reporting Service of the National Marine Fisheries Service, Miami, Florida

[a]Out of season landings included for 1972 and 1973 were 782,374 pounds and 1,504,480 pounds, respectively. These are landed in Florida from foreign waters during the Florida closed season.

APPENDIX C

TOTAL PRODUCT AND MARGINAL PRODUCT
EQUATIONS FOR FIRM HARVEST FUNCTION MODEL

(III) -- TRAPS

$$\ln q = 4.41843 + .7577 \ln x_1$$

$$\ln MP_{x_1} = 4.07715 - .2423 \ln x_1$$

(IV) -- PEK

$$\ln q = 9.367628 + .4359 \ln x_2$$

$$\ln MP_{x_2} = 8.5787272 - .5601 \ln x_2$$

(VI) -- WEEKS

$$\ln q = 7.985025 + .3721 \ln x_3$$

$$\ln MP_{x_3} = 7.101433 - .6279 \ln x_3$$

(VII) -- LOWD

$$\ln q = 7.4399502 + .3088 \ln x_4$$

$$\ln MP_{x_4} = 6.526395 - .6917 \ln x_4$$

(VIII) -- DAYS IN SET PERIODS

$$x_2 = 7/z$$

$$\frac{\partial q}{\partial z} = 4.23501\, x_1^{\beta_1} x_3^{\beta_3} x_4^{\beta_4} z^{-(\beta_2 + 1)} = .12116\, z^{-1.43991}$$

$$\ln MP_z = 9.40232 - 1.43991 \ln z$$

Table B1. Comparison of spiny lobster production practices by craft length for firms sampled, Florida Keys, 1973-74 season, economic study of Florida spiny lobster industry

| Item | Unit | Craft length (feet) | | | |
|---|---|---|---|---|---|
| | | 16-22 | 24-28 | 31-36 | 40-55 |
| Traps fished | no. | 341 | 561 | 842 | 809 |
| Traps lost: | | | | | |
| Number | no. | 98 | 193 | 318 | 371 |
| Percent | % | 29 | 34 | 38 | 46 |
| Traps fished per day | no. | 139 | 190 | 202 | 272 |
| Hours fished per day | hrs. | 7 | 8 | 8 | 9 |
| Pulls per season | no. | 27 | 27 | 25 | 27 |
| Weeks fished | wks. | 35 | 36 | 33 | 25 |
| Trips per season | no. | 66 | 103 | 89 | 48 |
| Boat and vessel size: | | | | | |
| Length | ft. | 20 | 26 | 34 | 46 |
| Width | ft. | 7 | 9 | 12 | 15 |
| Volume of Lobsters: | | | | | |
| Per trap | lbs. | 18 | 22 | 22 | 20 |
| Per week | lbs. | 175 | 339 | 549 | 636 |
| Per trip | lbs. | 93 | 118 | 204 | 331 |

Note: Data reflect averages for classes of craft size

## APPENDIX I

(Table 18 Computation )

1. $X_1$ assumed equal to 1000, 800, 700, 618, 500, 4[illegible]

2. $X_2^* = \frac{465,173,997.252}{(4,773,480.707) - \frac{1,439,976,169}{X_1}}$

3. $Q_B = 8,610,545.714 = \frac{1,439,976,169}{X_1}$

4. $Q_A = 9,773,480.707 - \frac{1,439,976,169}{X_1} - \frac{465,173,997.252}{X_2}$

5. $TC/X_2 = 1,876 + 11.55X_1$

6. $\pi/X_2 = \frac{Q_B\ (1.08)}{400} - TC/X_2$

7. $\pi/X_{2_A}^* = \frac{Q_A\ (1.08)}{X_2^*} - TC/X_2$

8. $\%\ \Delta\ \pi/X_{2_A}^* = \frac{\text{Column 7}}{\text{Column 6}} - 1$

9. Maximum State Revenue = (Column 10) x (Column 2)

10. Maximum License Fee = (Column 7) - (Column 6)

11. License Fee assumed
    - $20,000 for 1000 traps per firm
    - 18,000 for 800 traps per firm
    - 15,000 for 700 traps per firm
    - 13,000 for 618 traps per firm
    - 10,000 for 500 traps per firm
    - 5,000 for 429 traps per firm
    - 4,000 for 350 traps per firm
    - 3,000 for 200 traps per firm

12. $\%\ \Delta\ \pi/X_{2_A}^{**} = [\text{Column (7)} - \text{Column (11)}] \div [\text{Column (6)}] - 1$

13. State Revenue = (Column 11) x (Column 2)

14. Administrative Revenue = (Column 13) - [(Column 6) x (Column 16)]

15. % Δ
Tot. Ind. = [(Column 7) x (Column 2)] ÷ [(Column 6) x 400] - 1
w

16 $X_2^{**}$ = 400 - Column (2)

17. B.E.C. = [(Column 5) + (Column 11)] ÷ [(Column 1) x (1.08)]

APPENDIX I

Spaces provided for answers have been omitted from the original thirteen page questionnaire for inclusion in this text. The questions and multiple choice answers are the same. A map of the study area used to identify the actual fishing grounds for each fisherman has also been excluded.

(CONFIDENTIAL: Please do not give name)

SPINY LOBSTER FIRM SURVEY QUESTIONNAIRE

Please answer all questions based on 1973-74 season. Answer all questions as accurately as possible. If the exact answer cannot be recalled, please give your best approximation. If additional space is needed to answer (or simply comment on) a question use the back of that page and properly indicate additional comments.

I. DESCRIPTION OF LOBSTER PRODUCTION UNIT

A. Operation Unit: ( ) Vessel Boat
1. Fabrication (i.e., wood, fiberglass, steel, etc.)
2. Length (feet), Breadth (width) (feet)
3. Depth (feet), Draft feet (loaded) (feet)
4. Gross Tons, Net Tons
5. Engine Make, Horsepower
6. Age of Vessel, Age of Engine
7. Top speed: Empty, Loaded, Average Speed

B. Method and Crew:
1. Type ( ): Trap, Diving, Hull Net, Other
2. If trap: Single, Trot Line
3. Number of men in crew excluding captain
4. Approximate age of regular crew members (4 blanks)
5. Does a single trip involve more than one day away from port? Yes, No; if yes, what is the average length of time away from port per trip? (Days)

C. Gear:
1. Traps: a. Average number of traps fished in each month.
b. Maximum number of traps fished at any one time.
2. Electronic equipment on board. Give make and model number
3. Method used to haul traps: if hydraulic, please give capacity, size, and make if known.
4. Preservation techniques used? Live, Ice, Freeze, Other
5. Please list other gear used but not listed above

## II. FISHERMAN'S LOBSTER PRODUCTION TECHNIQUE

A. Materials and Style of gear.

1. Trap Design
   a. Briefly describe trap style
   b. What type of throat structure is used?
   c. How many entrances do you have and where are they located?
   d. Is a bait cap used? Yes, No
   e. Type of material used? Is it readily available?
2. a. What type of bait do you use?
   b. Why do you prefer this type?
   c. On the average, how often do you have to replace the bait in a trap?
   d. Is it easy to acquire the bait you are using?

B. Description of fishing ground and fishing intensity

1. Please draw areas on the map on the next page as shown in the example. Then number each area consecutively (beginning with #1) based on the amount of fishing you do in that area (i.e., area 1 is fished most by you)
2. For the areas you have indicated on the map please give your best answer to the following questions describing each area:

   Area # (use map) (1 , 2 , 3 , 4 , 5 , 6 , 7 , 8)
   (1) Approximate distance from home port (miles)
   (2) Average traveling time from home port to each area (minutes)
   (3) Bottom conditions (enter letter) a. rocky/coral, b. sandy, c. grass; d. other
   (4) Average depth (feet)
3. Please indicate your best estimate of the following information for the three major areas you fished for the following months: (a) average depth, (b) average water temperature, (c) average number of traps (See map attached to back of questionnaire)

   1973-74 season (Aug - Sept - Oct - Nov - Dec Jan Feb , Mar)
   Area # (get from map)
   (a) Average # traps
   (b) Average water temperature
   (c) Average number traps made

   (Dotted lines used to separate more than one area fished for a month )
4. List all ports at which you landed during season. (8 blanks)
5. Daily Activity
   a. What is the average hours per day worked? (From departure of port to return) (Hours)
   b. Of the above hours, approximately how many are spent actually hauling traps? (Excluding traveling between fishing grounds) (Hours)
   c. How many traps can your operation pull and shoot per hour?
   d. On the average, approximately how many trips did you make per week for each month? (1973-74 season) (Aug - Mar )
   e. What is the average length of time traps are between hauls for each month? (Days)
   f. Approximate number of days of bad weather which prevented you from fishing for each month? (If unknown, give best estimate for total season (Season total) (Aug - Mar )

## III. COSTS OF PRODUCTION

A. Initial Costs (fixed costs):
1. Value of vessel (boat) (Excluding gear, electronic, and hydraulic equipment)? ($ ____)
2. Type (make) and value of electronic equipment on board? Value $ ____. Describe
3. Replacement value of engine? $ ____
4. Value of Hydraulic and other equipment on board? Value $____. Describe
5. Cost of insurance?
   a. Protection and indemnity (P & I)? ($ ___)
   b. Hull ($___)
6. Interest on Loan? ($ ___)
7. Fishing and vessel (boat) licenses and permits? ($ ___)
8. Trap construction:
   a. Number of traps built for 1973-74 season?
   b. Cost of line? ($) Type used
   c. Cost of wood? ($) Type used
   d. Cost of buoy? ($) Type used
   e. Cost of labor used in building traps? ($)
   f. Other costs (i.e. cement, oil, nails, wire)? (Specify amount)
9. Please describe and give value of other miscellaneous initial expenses?

B. Operating Costs (Variable Costs): 1973-74 season. Please leave blank if the item does not pertain to your operation.

| Item | Amount Used | Total Cost ($) |
|---|---|---|
| 1. Fuel (gals.) | | |
| 2. Oil (gals.) | | |
| 3. Bait (lbs.) | | |
| 4. Ice (lbs.) | | |
| 5. Groceries | | |
| 6. Other miscellaneous trip expenses | | |
| 7. Labor costs | | |
| a. Captain share (%) | | |
| b. Crew share (%) | | |
| c. Boat share (%) | | |
| d. Wages (hours) | | |
| e. Bonuses | | |
| f. Labor taxes | | |
| g. Other (specify) | | |
| 8. Maintenance and repair costs | | |
| a. Hull | | |
| b. Engine | | |
| c. Electronic equipment | | |
| d. Other machinery | | |
| e. Gear (traps) | | |
| f. Other (specify) | | |
| 9. Cost of trap losses No. of traps lost | | |
| 10. Other expenses (Specify) | | |

## IV. PRODUCTION AND EARNINGS

1. What percent of your total income is earned from lobster fishing?
2. Please complete the following table on monthly landings and values to the best of your knowledge. (1973-74 season)

| 1973-74 Season | Landings & Value (August - March) | Total |
|---|---|---|
| Lobster (lbs.) | | |
| Lobster ($) | | |
| Finfish (lbs.) | | |
| Finfish ($) | | |
| Other (lbs.) | | |
| Other ($) | | |

3. Please answer the following questions to the best of your knowledge. Space for answers is provided in the table.
   A. What is the average size of legal lobsters landed for each month?
   B. How many pounds of "shorts" do you see in your traps per trip, on the average, for each month?
   C. What is the average number of traps lost each month?
   D. How many pounds of lobsters do you believe were stolen from your traps, on the average, each month?

| | 1973-74 (August - March) | Total |
|---|---|---|
| Question A | | |
| Question B | | |
| Question C | | |
| Question D | | |

4. Please check the range of your total earnings from lobster fishing only for the 1973-74 season. (Below $2,000 to above $30,000)
5. If you fished and if you recall, what was your approximate total season landings and total number of traps fished each season as shown in the table.

| | (72-73) | (71-72) | (70-71) | (69-70) | (68-69) |
|---|---|---|---|---|---|
| Total Landings | | | | | |
| Total Traps Fished | | | | | |

6. What do you feel would be the most efficient combination of the following if you could design the ideal operation unit?
   A. Vessels: Make, length, Width, Gross Tonnage, Fabrication
   B. Engines: Make, Horsepower
   C. Size of crew
   D. Electric Equipment
   E. Hydraulic Equipment
   F. Total Number of Traps
   G. Approximate Cost of Complete Operation Excluding Crew and Traps ($)
   H. Given this "Dream" Operation Unit Approximately How Many Pounds Do You Believe You Could Have Landed in 1973-74 Season?

V. ABOUT THE CAPTAIN AND HIS VIEWS ON MANAGEMENT AND REGULA[illegible]

1. The Captain
   A. Age (years)
   B. Years lobster fishing (years)
   C. Father's occupation
   D. What generation lobster fishermen are you
   E. Education (grade school, high school, college)

2. Is your lobster operation considered single firm, partnership, or Corporation?

3. Is there any cooperative activity with other fishermen (i.e. sharing of labor)? Explain.

4. Do you find that the size of lobsters has decreased over the years? Yes. No. If so, by how much or in what manner?

5. What are the major factors used by you to determine when and where to fish certain areas? (i.e. with respect to such things as tides, month, wind, moon, temperature, barometer readings, etc.)

6. If the landing of shorts was legal, how many pounds of shorts could you have landed in the 1973-74 season in addition to the legal lobsters you landed? (lbs.)

7. How many pounds of shorts do you feel were landed in your area in the 1973-74 season? (lbs.)

8. If you were not a lobster fisherman what other occupation would you have chosen based on your qualifications.
   A. Other fishing (specify) Estimated income ($)
   B. Non-Fishing (specify) Estimated income ($)

9. What kind of regulation or management would you recommend with respect to the following:
   A. How long should the season be? Why?
   B. What months should the season include? Why?
   C. Should the number of licenses be limited? If so, how and to whom?
   D. What is the maximum amount you are willing to pay for a license?
   E. What should a lobster's legal carapace length be set at? (inches)
   F. Other comments.

Table XI Spiny Lobster Landings, Landings and Values, Monroe County, Florida, 1967-68 Economic Study of Florida Spiny Lobster Industry

| | 1967[a] | 1972[a] | 1971 | 1970 | 1969 | 1968 | 1967 | 1966 | 1965 | 1964 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Landings (lbs) | 2,801,640 | 2,839,178 | 2,651,181 | 2,865,700 | 2,420,168 | 2,801,618 | 2,118,168 | 2,850,191 | 2,816,[illegible] | 2,663,[illegible] |
| Total Value ($) | 3,321,000[b] | 2,852,184 | 2,231,181 | 1,800,000 | 2,168,018 | 2,318,054 | 2,018,168 | 2,618,859 | 2,664,168 | 2,[illegible] |
| Price ($/lb) | 0.64 | 0.81 | .86 | .0811 | .81 | .82 | .81 | .81 | .82 | .82 |
| Traps (gear) | 681,48 | 681,864 | 681,168 | 681,000 | 684,655 | 67,800 | 68,879 | 66,588 | 69,168 | 68,000 | 68,859 |
| Traps per trap | 68.18 | 34.81 | 32.98 | 35.98 | 46.68 | 68.81 | 26.82 | 48.96 | 68.81 | 38.68 | 81.18 |
| Fishermen per trap | 61.59 | 37.98 | 25.81 | 28.68 | 34.18 | 26.38 | 18.11 | 68.18 | 67.68 | 18.68 | 81.98 |
| Fishermen Year-round | 811 | 328 | 811* | 281 | 198 | 68 | 148 | 104 | 54 | 65 | 44 |
| Part Year | 818 | 823 | 888 | 838 | 818 | 114 | 818 | 300 | 198 | 188 | 813 |
| Casual | 38 | 37 | 39 | 11 | 79 | 18 | 88 | 18 | 24 | 108 | 11 |
| TOTAL | 8 6 | 888 | 841 | 198 | 818 | 548 | 897 | 814 | 318 | 818 | 854 |
| Boats | 1 1 | 138 | 188 | 212 | 118 | 138 | 824 | 118 | 148 | 818* | 162 |
| Fishermen per boat | 8.54 | 8.18 | 1.32 | 1.88 | 8.88 | 8.18 | 8.88 | 8.81 | 1.88 | 8.18 | 1.88 |
| Vessels | 188 | 123 | 138 | 818 | 59 | 881 | 88 | 18 | 88 | 8.88 | 1.88 |
| Fishermen per vessel | 8.18 | 8.81 | 8.83 | 2.88 | 8.81 | 8.35 | 1.81 | 8.88 | 8.88 | 8.88 | 1.88 |
| Crew Size | 8.[illegible] | 1.58 | 8.841 | 8.888 | 8.138 | 8.888 | 1.138 | 828 | 888 | 88 | 1 |
| Crew Size per vessel | 51.18 | 81.31 | 18.88 | 2.88 | 2.81 | 88.88 | 88.88 | 18.11 | 11.32 | 8.8 | 18.3 |
| Gross Income ($ and Income) | 188 | 1.8 | 811 | 181 | 888 | 818 | 888 | 888 | 818 | 818 | 5 |
| Per vessel per month | 88.818 | 8.888 | 18.881 | 88.888 | 8.888 | 18.888 | 8.888 | 88.888 | 88.818 | 18.867 | 18.8 3 |
| Earnings per Fisherman | 88.888 | 18.811 | 81.811 | 8.888 | 12.838 | 18.138 | 1.588 | 8.188 | 11.818 | 8.848 | 8.8 3 |
| Trips per Fisherman | 418.81 | 818.81 | 881.98 | 488.18 | 568.87 | 853.13 | 381.82 | 371.59 | 818.18 | 298.58 | 322.81 |
| Days per Fisherman | 18.88 | 19.68 | 18.38 | 88.81 | 18.88 | 78.38 | 81.18 | 88.84 | 11.91 | 18.52 | 88.45 |

Source U.S. Department of Commerce, NOAA, NMFS, Southeast Fisheries Center, Miami, Florida

[a] Adjusted for mid-el season landings. Actual data recorded for Monroe County, before adjusting for mid-el season [illegible] landings = 8,181,489 (1981) & 818,018 (1972)
Total value = 13,888,181 (18 & [illegible] 826 (88/2)

[b] 1918 total value calculated by: 2,998,235 = 886 8 - 3,823,838

[c] Estimated

[d] Water temperature was calculated from the monthly mean surface water temperature for August thru March of each season. The data for South Miami and Key West stations were averaged to obtain this value

Monroe County
Mid el Season Landings

| | April | May | June | July | Total |
|---|---|---|---|---|---|
| 1966 | 0 | 34,818 | 88,864 | 88,818 | 188,268 |
| 1968 | 81,088 | 83,681 | 88,818 | 88,341 | 238,828 |

Table L1. Data used to estimate firm harvest function, 1973-74 survey of spiny lobster captains, economic study of Florida spiny lobster industry

| Landings (pounds) | Traps ($x_1$) | Rounds per week ($x_2$) | Weeks ($x_3$) | Craft size ($x_4$) | Area fished ($x_5$,$x_6$) | Length | Width | Landings (dollars) | Survey I.D. Code |
|---|---|---|---|---|---|---|---|---|---|
| 3052 | 140 | .6240 | 36 | 154 | 1, 0 | 22 | 7 | 3336 | 105 |
| 14000 | 832 | .8860 | 36 | 80 | 1, 0 | 16 | 5 | 1498 | 108 |
| 10254 | 377 | 1.1200 | 28 | 140 | 1, 0 | 20 | 7 | 10254 | 110 |
| 2963 | 85 | .7980 | 36 | 96 | 1, 0 | 16 | 6 | 3200 | 111 |
| 5000 | 448 | .6750 | 36 | 154 | 0. 0 | 22 | 7 | 5350 | 204 |
| 6616 | 365 | .9120 | 36 | 176 | 0. 1 | 22 | 8 | 7148 | 302 |
| 2996 | 140 | .8300 | 36 | 176 | 0. 1 | 22 | 8 | 3176 | 305 |
| 13613 | 851 | .5790 | 36 | 234 | 1. 0 | 26 | 9 | 14566 | 101 |
| 22000 | 401 | .6610 | 36 | 234 | 1, 0 | 26 | 9 | 23540 | 109 |
| 7103 | 665 | .7700 | 36 | 200 | 0, 0 | 25 | 8 | 7600 | 201 |
| 12000 | 560 | 1 0390 | 36 | 252 | 0, 0 | 28 | 9 | 12840 | 203 |
| 8000 | 260 | .7620 | 36 | 240 | 0, 1 | 24 | 10 | 8560 | 304 |
| 16531 | 800 | .6330 | 36 | 252 | 0, 1 | 28 | 9 | 20664 | 306 |
| 6171 | 396 | .6670 | 36 | 208 | 0, 1 | 26 | 8 | 7171 | 307 |
| 15000 | 776 | .5000 | 36 | 341 | 1, 0 | 31 | 11 | 16050 | 102 |
| 15973 | 597 | .7950 | 36 | 408 | 1, 0 | 34 | 12 | 17055 | 103 |
| 17000 | 648 | .7980 | 36 | 432 | 1, 0 | 36 | 12 | 18190 | 104 |
| 17000 | 647 | .7950 | 36 | 340 | 1, 0 | 34 | 10 | 18190 | 106 |
| 18000 | 1103 | .9300 | 15 | 468 | 0, 0 | 36 | 13 | 19260 | 202 |
| 8500 | 498 | .5720 | 36 | 330 | 0, 0 | 33 | 10 | 9095 | 205 |
| 35308 | 1625 | 1 0480 | 36 | 468 | 0, 0 | 36 | 13 | 37780 | 206 |
| 16333 | 1251 | .8900 | 13 | 690 | 0, 0 | 46 | 15 | 17866 | 207 |
| 16575 | 716 | 1.0810 | 36 | 574 | 0, 1 | 41 | 14 | 17520 | 303 |
| 16724 | 619 | .8900 | 36 | 480 | 0, 1 | 40 | 12 | 17903 | 308 |
| 13979 | 622 | 1 3950 | 15 | 1045 | 0, 1 | 55 | 19 | 17800 | 310 |

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## BIOGRAPHICAL SKETCH

[illegible] Williams, the son of Jess and Ann Williams, was born July 29, [illegible] in Houston, Texas. The major portion of his life was spent in a small rural community located in the southern portion of Louisiana, community referred to as "Cajun country."

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In September 1971 he enrolled in the Graduate School of the University of Florida, Gainesville, Florida. As a graduate research assistant in the Food and Resource Economics Department he pursued the degree of Doctor of Philosophy. In March, 1975 he was employed by Virginia Polytechnic Institute and State University as an assistant professor in the Department of Agricultural Economics.

Joel Sylvan Williams is married to the former Susan Emily Tate, a Cajun queen from Big Mamou, Louisiana. He is a member of Omicron Delta Kappa, Gamma Sigma Delta, Omicron Delta Epsilon, and the American and Southern Agricultural Economics Associations.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Fred J. Prochaska Chairman
Associate Professor of
Food and Resource Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. W. McPherson
Professor of Food and Resource
Economics

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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